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*Belle Fourche Valleys and Uplands**

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Possibly to a few, an irrigation project in a semi-arid region is anomalous. Even to geographers, northern Great Plains irrigation is likely to present many features unpredictable from the available studies of strictly arid lands and their enclosed oases. The Belle Fourche Project, ordinarily rather vaguely thought of merely as one of the larger irrigated units of the Great Plains, remains practically untouched in geographic literature. Reconnaissance studies of the Great Plains have consistently avoided the irrigated districts, especially the federal projects. In part this omission results from the character of these studies, but to some extent such regions have been excluded fom survey on logical grounds. There is a belief, quite firmly entrenched, that the irrigated areas of the Great Plains are essentially different from the region in which they lie; like the Black Hills, whose hundreds of mountain-born brooklets furnish the life-blood of the Belle Fourche Project, the irrigated areas are felt to be in the region but not of it. Supposing this to be true, it would apply with the greatest force to regions placed under irrigation by the United States Reclamation Service —areas presumably possessing the largest number of artificial elements. Baker has voiced the majority opinion: "The agriculture of the irrigated districts has not been described because it is not characteristic of the Great Plains region."[1]

*This study was aided with funds granted for that specific purpose by the Rockefeller Foundation through the University of Minnesota.

[1]Baker, O. E.: The Agriculture of the Great Plains Region, *Annals of the Association of American Geographers*, Vol. 13, 1923, p. 164.

On the contrary, increased familiarity with the Belle Fourche Project resulting from a summer's field work therein, has led to two conclusions: (1) that culturally as well as physically this project bears the unmistakable imprint of the Northern Piedmont of the Black Hills, and (2) that this project departs in so many fundamental ways from the conventional pattern of irrigated valleys and enclosed oases that one seems to be dealing with a distinctive type.

I: NATURAL ENVIRONMENT OF THE BELLE FOURCHE PROJECT

The Belle Fourche Project—taking up the second conclusion first—is a collection of irrigated slopes and occasional irrigated plains separated more or less completely from one another by broad areas of rolling and largely unoccupied steppe. The steppe land rises as islands above verdant lowlands, or extends as isthmuses and peninsulas from the higher country marginal to the Belle Fourche Valley, interlacing the whole region like great cross-ribs between which lie patches of irrigable land. Continuous areas of flat-to-gently-rolling land do occasionally dominate the scene, but characteristically, the irrigated lands are hillsides with slopes of from five to fifteen degrees. Probably in regions of more favorable landforms, much land here declared irrigable would be used for other purposes.

Curiously enough, the main body of irrigated land lies not along the river whose name identifies the project, but rather along the valleys tributary to the main stream and entering it at frequent intervals eastward from the city of Belle Fourche to a point about thirty miles downstream. Originally these tributaries were typical steppe-land wet-weather washes. With no trustworthy sources of supply, except in modern times that of waste irrigation water, they fluctuate with the rainfall rhythm and are narrow ribbons of shallow water in dry weather. Derivation of water from a common source seems not to be sufficient to unify a region possessing so few factors tending toward integration. For this reason the inhabitants are inclined to identify themselves with some section of the project (e.g. Horse Creek, the Vale region, Cottonwood Creek, the Arpan country) more often than with the Belle Fourche Project as a whole. This attitude is to some extent inherited from the past, for before 1900 the only settlements included a few widely spaced ranches along the wooded creek bottoms from which

their owners controlled large areas of the surrounding range land. A quarter-century of irrigation has served to shrink notably the unoccupied intervales, but an irreducible minimum remains to preserve the original character of the region. This is indicated in data gathered by the Reclamation Service, for it appears that of the 80,481 acres classed as "possibly susceptible of irrigation", 61,620 acres are in actual fact irrigable, while the irrigated acreage falls to 36,195 acres.[2]

DRAINAGE PATTERN AND SURFACE CONFIGURATION

The drainage pattern of the Belle Fourche Project is its most distinctive natural feature. The crescentic course of the meandering Belle Fourche, the broad, shallow, east-trending depressions through which the winding creeks finally reach the main stream, the conspicuous inter-stream ridges which dominate the view on nearly every hand—these features boldly intrude themselves into the landscape through the cultural forms associated with irrigation.

[2] *Annual report of the Commissioner of Reclamation,* Bureau of Reclamation, United States Department of the Interior, 1930. Additional significant data appear in the following table:

Number of irrigated farms	726	
Total farm population	2271	
Cropped acreage	47955	acres
Estimated damage by seepage	10000	acres
Length of open drains	106	miles
Crops:		
Barley	4758	acres
Corn	2634	"
Oats	4437	"
Rye	553	"
Wheat	2180	"
Flax	532	"
Alfalfa (for hay and seed)	16811	"
Corn (for fodder)	1155	"
Other hays	2196	"
Sugar beets	8472	"
Pasture	3956	"
Livestock:		
Horses	2555	head
Beef cattle	2944	"
Dairy cattle	3907	"
Sheep	76469	"
Hogs	3321	
Fowls	38269	"

The crescentic course of the Belle Fourche River has been the subject of frequent observation in literature. Rising west of the Black Hills in Wyoming, the river flows in a broadly curving eastward course which above its confluence with the Cheyenne River nicely demarcates the Black Hills Piedmont. It is well established that this peculiarity has been acquired by successive stream captures and active headward erosion. Quoting: "The upper portion of this stream [the Belle Fourche] in Wyoming flows northeast in line with the Little Missouri of which it was formerly a part. From this locality the east-flowing Belle Fourche reaches the Missouri in 300 miles whereas the Little Missouri makes a circuit of 600 miles to the same point. . . . The captured headstream now turns at right angles to follow the Belle Fourche and, at the point of capture, the reenforced Belle Fourche has already entrenched itself 100 feet below the abandoned channel."[3] In this way, the Belle Fourche River became the chief tributary of the Cheyenne and, before diversion of water from its channel, brought to the main stream nearly all the drainage from the northern Black Hills.

In providing the facilities for irrigation, conceived in the early 1900's and commenced on a large scale by 1910, the local drainage pattern has been fairly etched into the landscape. To create the reservoir the Orman Dam, an earth-fill structure, was built across Owl Creek Valley, one of the northern tributaries of the Belle Fourche. The dimensions of the dam provide a convenient gauge of the several broad depressions in the bottoms of which the creeks meander to the main stream: having a maximum height of only 122 feet in the axis of the valley, it is 6200 feet in length. From the base of the dam lead two master canals (Fig. 1) which provide irrigation and domestic water to the entire project. Called simply the North and South Canals, they have an elevation of 2935 feet at the dam, and at their eastern extremities are some 300 feet lower. In order to encompass as much land as possible in their eastward course, the canals extend in contour-like fashion nearly to the heads of the tributary valleys which they successively meet in their gentle downward flow (Fig. 2). Thus, the Belle Fourche Project has digitate boundaries suggesting an oak-leaf in outline.

Inasmuch as the canal gradients exceed the general reduction of surface elevations to the east, the imaginary plane thus formed

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[3]Fenneman, N. M.: *Physiography of Western United States,* 1932, pp. 77-78.

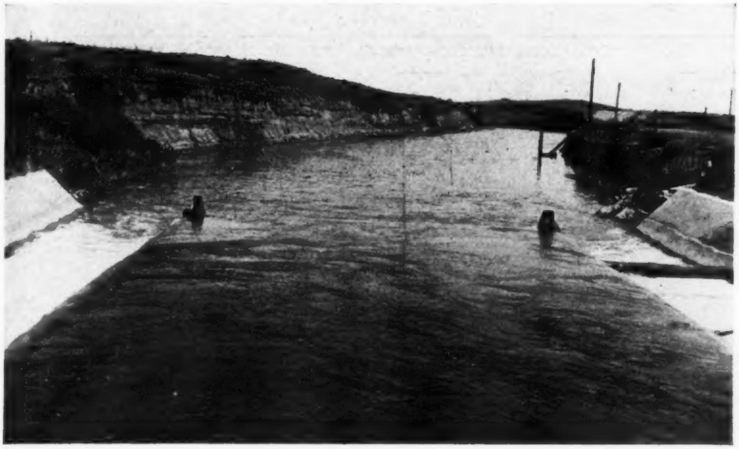

FIG. 1.—The North Canal at the dam spillway looking east. Most of the irrigated lands north of the Belle Fourche River are "under" this canal. The South Canal is similar in appearance but of smaller capacity.

FIG. 2.—The North Canal about 13 miles east of Figure 1. The head of water is not truly representative at this distance from the dam. Both canals are unlined trenches throughout except for occasional syphons and flumes. An alkali layer appears on the right bank. None of the land shown is irrigable.

between the two canals intersects many projecting hills and ridgetops. The upper limit of irrigation is a fixed plane sloping gently to the east. The lower limit, on the other hand, is highly irregular; in places altogether wanting, for occasionally the irrigated lands

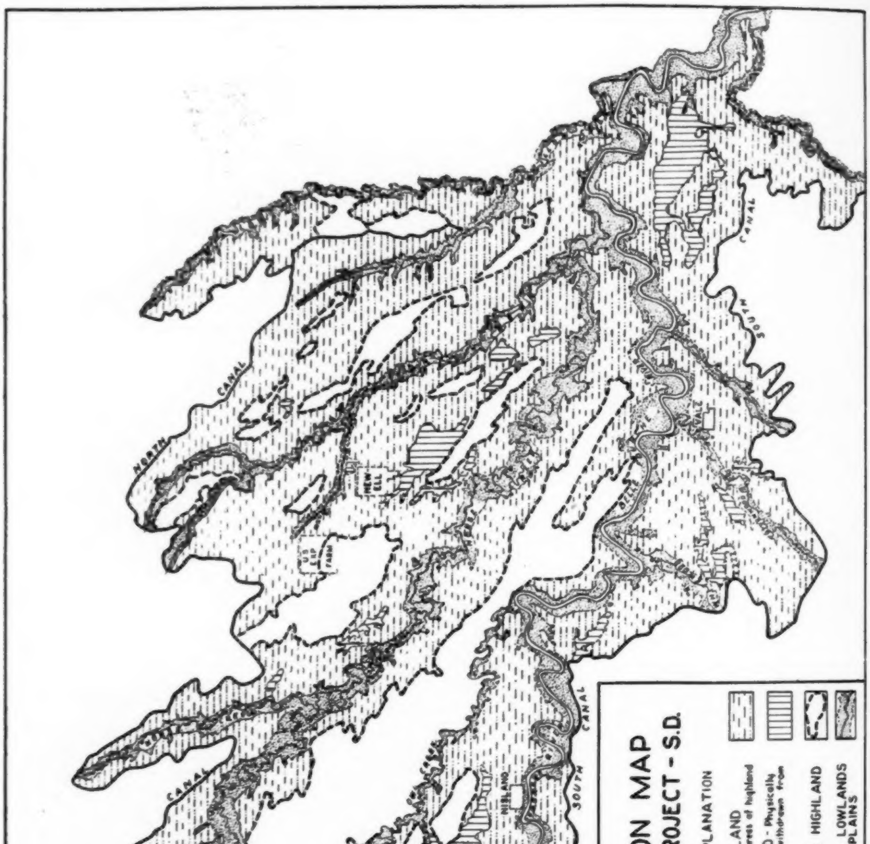
GENERALIZED
LAND CLASSIFICATION MAP
BELLE FOURCHE IRRIGATION PROJECT - S.D.
EXPLANATION
IRRIGABLE LAND
Including small areas of highland
SEEPED LAND - Physically irrigable but withdrawn from irrigable class
UNIRRIGABLE HIGHLAND
UNIRRIGABLE LOWLANDS AND FLOOD PLAINS
3 MILES
SOUTH DAKOTA
NEBRASKA
NORTH CANAL
SOUTH CANAL
BELLE FOURCHE RESERVOIR
FRUITDALE
NISLAND
NEW ELL

FIG. 3

extend far down the slopes and sweep completely across the narrow creek bottoms to the tree-bordered stream banks. More commonly, however, the lower limit of the intermediate zone of irrigation terminates in a frayed boundary some distance above the bottom lands, which are likely to have surface and soils unfavorable to this practice. The map, (Fig. 3), prepared from unpublished records at the Newell Reclamation Office, portrays the actual conditions.

The surface of the Belle Fourche area is not strikingly different from that of all this portion of South Dakota of which the simple and unqualified word "plain" is not adequately descriptive. Writing of northwest central South Dakota one observer says: "Though its topography is generally thought of as a plain, the word conveys an erroneous impression to most minds. While its general upland surface rises and falls through moderate range with gentle slopes, yet upon this [surface] conspicuous masses and buttes rise quite abruptly to a height of one hundred or even four hundred feet. And, on the other hand, the rivers and water courses have cut a like distance below it, while along the larger rivers there are terraces often wide and sharply defined."[4]

The familiar classification of trans-Missouri (or, more popularly, Westriver,[5] South Dakota, as the Missouri Plateau section of the Great Plains is doubtless a recognition of the higher relief of this plains region.[6]

Noteworthy among the surface features are the great length and continuity of the slopes. These remain essentially unbroken except in the axes of the valleys where the flat, narrow creek bottoms are found sharply incised by their streams. One expectantly looks for, but rarely finds, critical differences in angle of slope above and below the irrigation canals—altitude alone determining the location of the canal. The ridge tops have accordant summits giving the sense of limitless expanse to the undulatory

[4]Todd, J. E.: Preliminary Report on the Geology of Northwest Central South Dakota, *South Dakota Geological Survey, Bulletin No.* 4, 1908, p. 17.

[5]"Westriver", a commonly used expression west of the Missouri River in South Dakota, seems worthy of preservation in geographic literature, despite its journalistic qualities. Its wide use indicates that the Missouri River is popularly regarded as a significant boundary.

[6]Fenneman, N. M.: Physiographic divisions of the United States, *Annals of the Association of American Geographers,* Vol. 18, 1928, Division No. 44 (revised map).

plain (so typical of the Great Plains) but in detail the summits present variety of form. Some are essentially flat with water-worn gravels; probably ancient stream channels. Occasionally cone-shaped mounds surmount the general upland level. These are analagous certainly in appearance and probably in origin to the tepee buttes identified by Darton northeast of the project.[7] In silhouette, as commonly viewed because of their location on the horizon, these symmetrical mounds are most striking, contributing a unique and long-remembered detail to the natural landscape. Less frequently, the upland is surmounted by bold, tabular-shaped masses, commonly called buttes, many of which are real land-marks in the region. Miller Butte within the project, and Bear Butte and Castle Rock to the south and north of it respectively, stand out conspicuously on the horizon from almost any position. The west slopes of the ridges tend to be steeper than their eastern slopes; in this respect the ridges suggest cuestas (Fig. 4).

FIG. 4.—Looking northeast to the steep west face of the ridge overlooking Owl Creek. This is the same ridge which, farther south, towers above the Belle Fourche River. In the foreground is a typical alkali flat marking an area of shallow soil and poor drainage. In the middle distance, beyond the alkali flat, is an intermediate area of irrigable land.

There are, however, some important exceptions to the general rolling and undulatory character of the Belle Fourche area. The surface frequently gives way to steep-sided, though not deep swales, sloughs or (to use the local expression) coulees. In the north-

[7] *Geologic Atlas of the United States, No.* 209, p. 2 (Surveyed 1904). Darton, N. H.: Newell Folio, United States Geological Survey.

western part of the project, in what is known as the Arpan region, lies an extensive plain with an eastward slope so gentle as to escape detection with the naked eye. This area, presenting by its lack of relief a fundamental contrast to the rest of the project, has been identified as a lacustrine plain. South of the Belle Fourche River, in the Vale region, the land relief is also more subdued than that of the adjacent regions.

SOILS

The Belle Fourche area lies in the northern division of the dark brown soil belt in which the layer of carbonate accumulation in mature soils is more than a foot beneath the surface.[8] Factors strictly local in character have, however, introduced many variations from the type of soil characteristic of this climate and vegatation.[9] Soil colors are lighter than that of the general type: the dominant color is ashy-gray at the surface with light brown or yellow-brown colorations in the lower horizons. The latter colors commonly change to gray upon exposure of the sub-soil.

The lighter surface colors are in part the result of location toward the western limits of the dark-brown soil belt which grades imperceptibly into the brown belt of the more arid climates. Of still more importance in this connection is the widespread development in the region of the Pierre Shale,[10] from the weathering of which fully two-thirds of the mature soils have been derived.[11]

The native gray color of this massive rock formation seemingly carries over into its weathered material, perhaps after having first passed through a stage in which brownish colors predominate; at least this is suggested by the rapidity with which the brownish colored soils of the present turn to light gray. This color dominates the whole landscape where barren of vegetation; even the water in the unlined laterals carries so much suspended material

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[8]Marbut, C. F.: Soils of the Great Plains, *Annals of the Association of American Geographers,* Vol. 13, 1923, p. 44 (map).

[9]The climatic type is BSkw (Koeppen-Geiger); the vegetation cover is largely plains grassland made up of grama and western wheat grass except along the water courses where western cottonwoods and willows prevail.

[10]Darton, N. H.: *op. cit.*

[11]Strahorn, A. T. and Mann, C. W.: Soils of the Belle Fourche Area, S.D., United States Department of the Interior, *Bureau of Soils, Field Operations* 1908, p. 13.

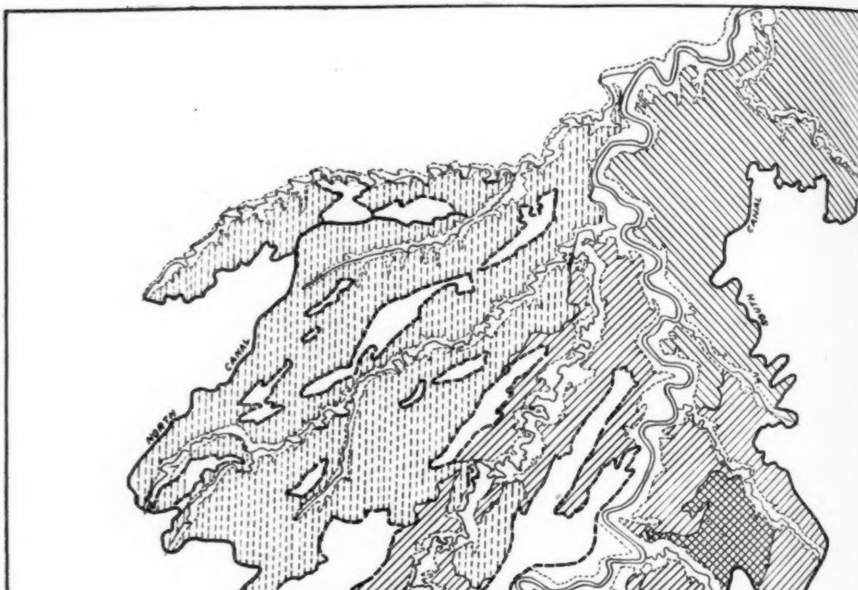

GENERALIZED
SOIL TYPE MAP
BELLE FOURCHE IRRIGATION PROJECT - S.D.
ADAPTED FROM BUREAU OF SOILS BULLETIN - 1908
PIERRE CLAY
ORMAN CLAY
PIERRE CLAY LOAM
VALE FINE CLAY LOAM
VALE LOAM
OVERFLOW LAND including meadow and gravelly material
HIGH UNIRRIGABLE AREAS Not mapped
NORTH CANAL
NORTH CANAL
SOUTH CANAL
SOUTH CANAL
BELLE FOURCHE RESERVOIR
ORMAN DAM

Fig 5

that it is often indistinguishable in color from the land itself. Still another factor causing variation from the general soil type is the piedmont location of the Belle Fourche area. As stated by Marbut: "The Black Hills introduces a group of foreign soils . . . . the greater part of them consisting of light-colored timber soils similar to those of northern Minnesota and Wisconsin".[12] The upper portions of the remaining third of the surface soils are made up almost exclusively of material eroded from the varied rocks of the forested Black Hills and transported and laid down by streams issuing from that region.

Soil texture is extremely variable, ranging from the strictly clay soils (46% of the total area), through the clay loams (20%) to gravelly and sandy loams (20%), and finally to loam itself (3%). For details of soil texture see footnote 13. The map, Figure 5, adapted and simplified from Strahorn and Mann, shows the distribution of the soil types.

Strips of Meadow Soil, varying in texture according to the source of the deposited material, fringe all the water courses. The northern tributaries, rising in areas underlain by shale and clay, are bordered by heavy, impervious clays to a depth of six feet; the southern tributaries, issuing from the higher "bench" lands of the piedmont and the foothills, have carried into the region and deposited material more sandy in character. Vale gravelly Loam (grouped on the map with the Meadow Soils) and Vale Fine Sandy Loam are also alluvial soils, but the latter largely occur above present stream courses, especially on old river terraces south of the Belle Fourche River. These soils are essentially a veneer, varying in depth from three to ten feet, resting upon the heavy, compact sub-soil derived from the Pierre Shale. The Vale Loam varies in texture from heavy to light. "The light or sandy phase consists of six feet of heavy, sticky, clay loam containing quantities of gravel. The heavier phase, to a depth of from twelve to thirty inches, consists of a loam. This is underlain by a clay loam, rarely a clay to a depth of six feet. . . . Below six feet the soil is heavier, and from twelve to sixteen feet rests upon either a heavy clay or on a bed of water-worn gravels."[13]

The Pierre Clay soil, the most widespread soil of the region, generally has a depth of over six feet, is extremely heavy and

[12]Marbut, C. F.: *op. cit.*, pp. 58-59.

[13]Strahorn and Mann, *op. cit.*, p. 17.

tenacious, and has a whitish or ashy-gray surface color. The Orman Clay soil, confined to a continuous body in the northwestern part of the project, is practically a reproduction of the Pierre Clay soil and was no doubt mapped as a separate type because of the supposed lacustrine origin of the material. The Pierre Clay Loam is not strikingly different from either the Pierre or Orman Clays, but has a more favorable texture. The surface color is the prevalent ashy-gray, its depth varies from twelve to thirty inches and is a "rather heavy clay loam, underlain to six feet by a heavy tenacious clay".[14]

The inhabitants of the Belle Fourche area speak of two kinds of soils: the gumbo (Pierre and Orman Clays and Clay Loams) and the Vale Soils. While obviously lacking in exactness, this classification groups the residual, clay-base soils together separate from the sandier soils south of the Belle Fourche River. Locally, the Vale soils are regarded as being preferable to the other types, largely because of their more favorable structure and texture. Well-informed residents of the region[15] quite properly do not regard the project soils as being distinguished by great fertility, but rather by strength and lasting power under proper care.

In the heavy character of the predominating soils and their compact sub-soils are to be found their greatest advantages as well as several elements of weakness. Such soils have made possible

[14]*Ibid.* p. 18. The facts regarding soil textures are summarized in the following table:

	% Fine Gravel	% Course Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	% Silt	% Clay
Vale Gravelly Sandy Loam	3.0	10.9	9.6	27.8	13.8	24.4	9.5
Vale Fine Sandy Loam	0.1	0.7	0.3	8.4	24.5	55.9	10.7
Vale Loam	0.4	3.3	4.2	15.6	20.1	31.9	23.9
Pierre Clay	0.2	1.1	1.4	5.5	13.0	43.0	35.0
Orman Clay	0.0	0.0	0.2	4.2	11.0	42.0	36.1
Pierre Clay Loam	0.1	0.5	1.9	11.1	21.5	44.4	20.0

[15]Mr. Beyer Aune, director of the United States Experimental Farm near Newell, Mr. F. C. Youngblutt, superintendent of the project, Mr. J. P. Seibeneicher and Mr. R. E. Pratt, chief clerk and office engineer respectively of the project, have been consulted on this and many other questions. The following individuals have also contributed valuable information during the course of the study: Messrs. J. H. Christian, F. H. Driscoll, William F. Long, Burt Goff, Govert Vanderboom, and the Reverend H. W. Jameson.

the irrigation of steep slopes, for gullies do not readily form in soils of this texture. Moreover, the clayey soils have a tendency to seal over at the surface following a copious irrigation, a condition making for the harmless run-off of excess water without gully formation. In the lands above the laterals, the moisture-retentive soils make unnecessary the preparation of fallow fields, and in the unirrigated lowlands, good growth of grass for pasture may be maintained. On the other hand, the clayey soils with impervious sub-structure hold potential elements likely to prove troublesome following their long-continued irrigation; and such troubles have appeared in recent years. Water-logging and alkali accumulation have spelled at least temporary disaster to many a section in the project owing to excessive soil water and slow natural drainage. Warning of this was made as early as 1908, but it was not until "seeped land" locally made its appearance that attention was paid to providing drainage in soils and sub-soils which, naturally, were poorly drained. Also, the heavy clay soils have largely discouraged leveling preparatory to irrigation. Minor surface irregularities added to the general predominance of slope have resulted in a large amount of water waste during irrigations. In seeking to moisten all parts of a field of uneven surface, the irrigator is wont to use much water in the realization that the excess will flow ineffectively away in the lower parts while perhaps by capillary action the higher portions become sufficiently moist. Waste of water is not merely the result of steep slopes and surface irregularities, however, but is equally a measure of the abundance of water usually available and carelessness on the part of the irrigators.

II: CULTURAL FEATURES OF THE BELLE FOURCHE PROJECT

It was observed earlier that, culturally as well as naturally, the Belle Fourche area is strictly a portion of the Great Plains. Casual travelers may cross the master canals of the project and be unaware of any marked change in landscape. Possibly for this reason conspicuous sign-boards have been placed alongside the entering highways informing the hurrying motorist that he is now entering one of the federal projects "where water is king" and giving an optimistic estimate of the amount of irrigable land.

Entering the project in summer from east and north is more striking than the approach from the south because in the latter direction dry land farms stretch along the roads for some distance. The most conspicuous landscape change consists of the cottonwood

trees here and there lining creeks and laterals or standing in groves near homes; possibly next one is impressed with the vivid green of the alfalfa fields and sugar beets. If the entrance be made in a year during which above-normal spring rainfall has occurred, there is little observable difference in the height and quality of the grain crops raised under the two systems of farming. However, in common with the Great Plains region as a whole, the critical spring rains are not always to be depended upon, with the result that, as in 1931, the contrast in the quality of the dry land and irrigated crops may be very great. April, May, and June are the normally rainier months, but the average annual rainfall of 17 inches represents a mode between extremes varying from 7 to 27 inches. As measured by numbers of homes the project is obviously more densely peopled than its surroundings, but residences and farmsteads of both areas are strangely alike in appearance and appointments.

Furthermore, the same system of land survey has been employed within the project as elsewhere with many interesting results appearing in the present landscape. It is noticed that the culture-pattern of the Belle Fourche landscape is the resultant of the partially successful attempt to superimpose a system of severe rectangularity on a natural landscape in which, largely because of irrigation, a more harmonious arrangement of the many culture forms would seem inevitable.

THE ROADS

The roads are the most important and familiar feature of the rectangular plan which, could it have been followed to its logical conclusion, would have produced a cultural pattern differing in no essential way from that of any other rural area subject to the same methods of land survey. The typical Belle Fourche roads, unmarked aloft by telephone poles, are graded but not adequately surfaced (rendering them all but impassable during and shortly after wet weather), and follow section lines almost without deviation. In only rare instances do roads follow one-sixteenth and one-thirty-second mile square survey lines, leaving as a result larger inter-road spaces than is commonly expected in mature irrigated areas. Even so, the project presents a marked contrast to the nearly roadless character of much of the surrounding country. (Fig. 10).

Such a road pattern is quite at variance with the arrangement

of trails and wagon roads before 1900. These have become almost completely effaced, but the earlier maps show that more circuitous ways of travel prevailed at that time. The present road, on the other hand, is seen to swerve from its straight line only at those rare points where low-lying swampy land, or a major meander in a creek or a particularly high elevation stand in its trajectory.

Two roads intersecting at Newell are noticeably in a separate class; much wider and well gravelled, these are the most traveled ways and all other roads focus upon them. The north-south highway (U. S. trunk highway 79), besides being a major line of travel to and from the Black Hills, forms, for about two blocks, the business street of the town of Newell, the principal trade center within the project (Fig. 6). To accomplish this dual purpose, the

FIG. 6.—Girard Ave., Newell, S. D. Except for the one-story business houses which line it for two blocks, it is representative of U. S. trunk highways 79 and 212. The view looks north from the south end of the rudimentary commercial core.

road has been offset a quarter-mile from the section line. Intersecting with this road at Newell is the main east-west highway (U. S. 212) which is improved from the town of Faith eighty miles east of the project, to and beyond the city of Belle Fourche.

FARM BOUNDARIES

Carrying out the road pattern in greater minuteness are the

rectangular boundaries of farms and many fields into which all the lower lands of the project are divided. Fence lines at eighth- and quarter-mile intervals are common and there has been a tendency to continue this arrangement in setting off fields only a few acres in extent. While this is true, yet the actual boundaries of productive areas and various land uses do not conform rigidly to the survey system but rather to surface features which, were it not for irrigation would probably pass unnoticed. Upper and nether field boundaries are usually curving lines formed by irrigation laterals and drainage ditches which, in effect, heighten the relief of the region by making insignificant features conspicuous.

IRRIGATION LATERALS

The cultural transformation of this region in progress for the past quarter-century has caused artificial drainage lines to become more prominent than the natural. Irrigation laterals, though clearly artificial, have assumed a position of real permanency and are today the most familiar form of surface drainage. Even in abandoned areas the laterals form a most conspicuous feature of the cultural landscape. The location of the lateral is usually rendered all the more apparent by a discontinuous line of cottonwoods and masses of perennial weeds, the latter occasionally impenetrable.

Generally speaking, the laterals have serpentine courses as they wind about the hillsides in maintaining as high an altitude as possible throughout their length. To accomplish this end, flumes and syphons are occasionally brought into use, but usually the lateral is an unlined open trench four or five feet deep and wide, paralleled downslope by the excavated material and nearly following the contour of the land. For this reason, in view of its function, the irrigation lateral frequently forms the permanent upper limit of the field, thereby replacing the straight line of the fence with the curved line of the lateral. The usual method of irrigation is thus "contour irrigation". Headgates in the government laterals divert water to the farm ditches which cross the hillsides at frequent intervals. Canvas or other temporary dams are placed across the ditches causing the water to overflow at low points of the downslope bank. The water then flows undirected across fields of alfalfa, native hay and grains, or in furrows through fields of corn, sugar beets and vegetables.

DRAINAGE DITCHES

The drainage ditch is more highly localized and much more conspicuous than the irrigation lateral. Necessary and valuable though it be, the familiar expression "a blot on the landscape" would perhaps correctly express the outsider's first reaction to seeing one. As a cultural form, the drainage ditch is recognized from afar by its excavated material—a long, rough mound of clay and broken shale scantily clad with weeds, the whole perhaps fifteen feet in height lying alongside the trench of about the same depth and width. The actual height of the excavated waterial is usually a measure of the depth of the shale, because the drain would largely fail in its function if it did not intercept the "hard-pan" lying beneath the unconsolidated material (Fig. 7). The

FIG. 7.—A near view of a drainage ditch south of Newell. In proportion to their size, the drainage ditches carry but little water, a condition emphasized in the view. The plane-table tripod (which provides a gauge of the depth of the drains), just reaches the water-table, a condition necessary to the proper drainage of the seeped lands.

drains are usually encountered in one of two situations. Some connect a series of sloughs, swales and coulees originally unconnected and without adequate outlet. In this case the drain marks the lowest elevations, so that a field which has for its upper boundary an irrigation lateral may abruptly terminate downslope at the

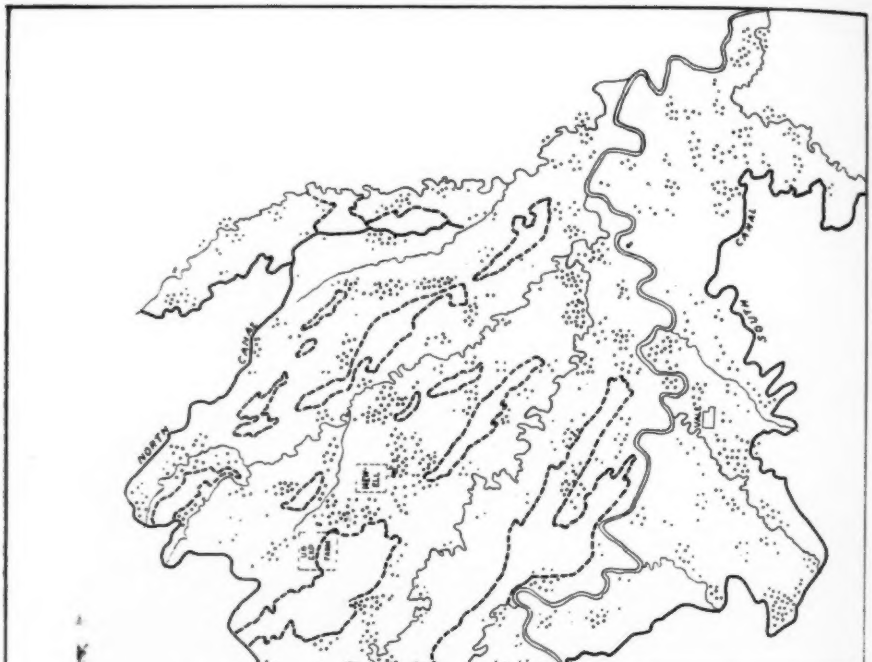

DISTRIBUTION OF FARM POPULATION
IN THE
BELLE FOURCHE IRRIGATION PROJECT
LOCATED BY FARMS, DATA FOR 1932
1 DOT REPRESENTS 1 INDIVIDUAL
0 1 2 3 4 MILES
NORTH CANAL
SOUTH CANAL
BELLE FOURCHE RESERVOIR

FIG. 9

embankment of a drainage ditch. In ground plan this type of drain resembles a small and highly conventionalized river system with short, straight "tributaries" entering the equally straight or roughly curving main channel at wide angles. Another characteristic location of these drains is paralleling, for short distances on the hillsides, the lower side of an irrigation lateral. In such cases the drains are designed to intercept the seepage from the unlined laterals.

Where possible the drains have been dug along fence lines and roads in order to be least in the way, but all too frequently compliance with the natural lay of the land requires that they traverse fields otherwise unified, to the constant annoyance and disadvantage of the farmers.

FARM HOUSES AND BUILDINGS

The farm builings (Fig. 8) conform to a common standard

FIG. 8.—A farmstead near Vale, typical of the average in the following particulars: small, frame house, scattered small outbuildings, small barn, with no silo or wind-mill, partially enclosed by luxuriant groves of cottonwoods.

reflecting, among other things, a similar period of origin. In the lands below the laterals they are quite uniformly distributed, the average being about four or five farmsteads to a section of land. This uniformity of distribution within the irrigated areas is reflected in the rural population map of the project (Fig. 9), the dots giving a reasonably accurate picture of the spacing of farmsteads. Sites of farmsteads present many variations but very commonly such sites are fixed by small patches of knolls of unirri-

gable land if these areas are within reasonable distance of the public roads. Some of the earlier residences were found to have been located with reference to driven wells for domestic water and these, unlike more recent structures, are not directly related to the present road system.

III: REPRESENTATIVE AREAS OF THE BELLE FOURCHE PROJECT

METHOD OF SELECTING THE TYPE REGIONS

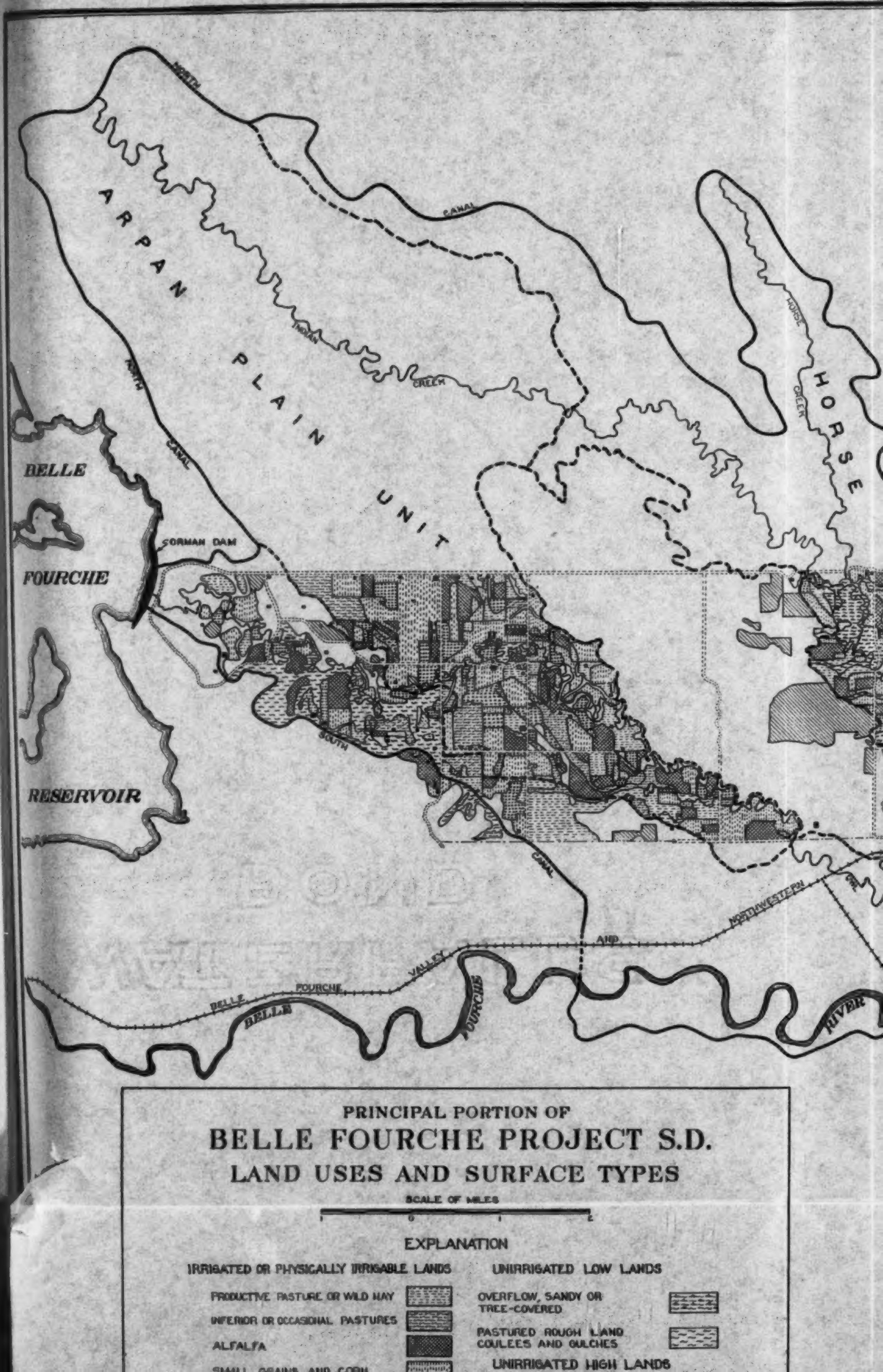
In order to take cognizance of all parts of a region so diversified, the preparation of cross-sections seemed essential. Experimentation soon revealed the inadequacy of simple cross-sections, while strips three miles in width could be depended upon to show reasonably typical conditions. A decision of equal importance was the selection of the strips to be thus trans-sectioned. Clearly the strips must run transverse to the major features and completely cross the irrigable lands in the widest portions of the project. Also they ought to include adjacent portions of the steppe beyond the project lands. It was observed that all this could best be accomplished by surveying a north-south and an east-west strip focussing on the government townsite of Newell. By a happy coincidence these strips would include not only Newell and its region, deserving first place in a geographic study of the project, but also the village of Vale and its reputedly superior service area.

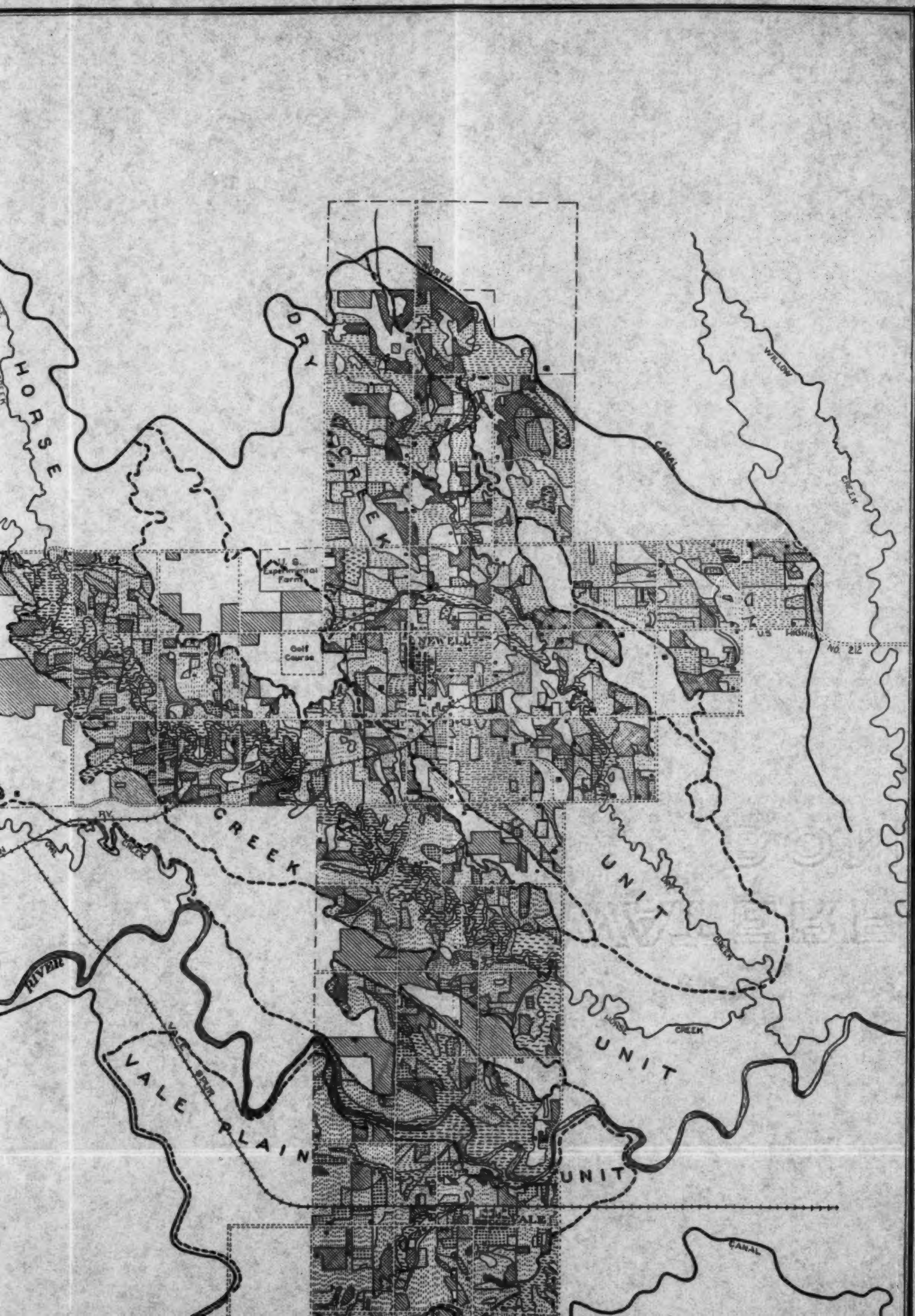
The purpose, as carried out, was to map the surface[16] with the accuracy made possible by a scale of one inch to a quarter mile and with the aid of field instruments and unpublished blue-prints of land classification prepared by Youngblutt and Pratt of the Reclamation Service. Upon completion of the trans-sections, study of the results made possible the accurate fixing of regional boundaries, and a concluding reconnaissance allowed for the interpolation of boundaries to include similiar regions not so mapped. The map, much simplified from the field plats, records the result of the survey (Fig. 10).

DRY CREEK AND THE NEWELL LOWLAND

Dry Creek occupies the eastern portion of a broad and shallow natural depression about twenty-five square miles in area. The

[16]The field mapping was done by the now familiar fractional notation system. In this area an additional tier of data was required, namely: I (irrigable land), N (unirrigable land), and NI (irrigability doubtful or obviously infrequent).


NORTH
ARPAN PLAIN UNIT
INDIAN CREEK
CANAL
NORTH CANAL
HORSE CREEK
HORSE
BELLE FOURCHE RESERVOIR
ORMAN DAM
SOUTH
CANAL
NORTHWESTERN
AND
VALLEY
BELLE FOURCHE
BELLE FOURCHE RIVER
PRINCIPAL PORTION OF
BELLE FOURCHE PROJECT S.D.
LAND USES AND SURFACE TYPES
SCALE OF MILES
EXPLANATION
IRRIGATED OR PHYSICALLY IRRIGABLE LANDS
PRODUCTIVE PASTURE OR WILD HAY
INFERIOR OR OCCASIONAL PASTURES
ALFALFA
UNIRRIGATED LOW LANDS
OVERFLOW, SANDY OR TREE-COVERED
PASTURED ROUGH LAND COULEES AND GULCHES
UNIRRIGATED HIGH LANDS



HORSE
DRY CREEK
NORTH
WILLOW
CREEK
CANAL
U. S. Experimental Farm
Golf Course
NEWELL
U.S. HIGHWAY NO. 212
RY.
CREEK
UNIT
CREEK
RIVER
HORSE CREEK
UNIT
VALE PLAIN UNIT
VALE
CANAL

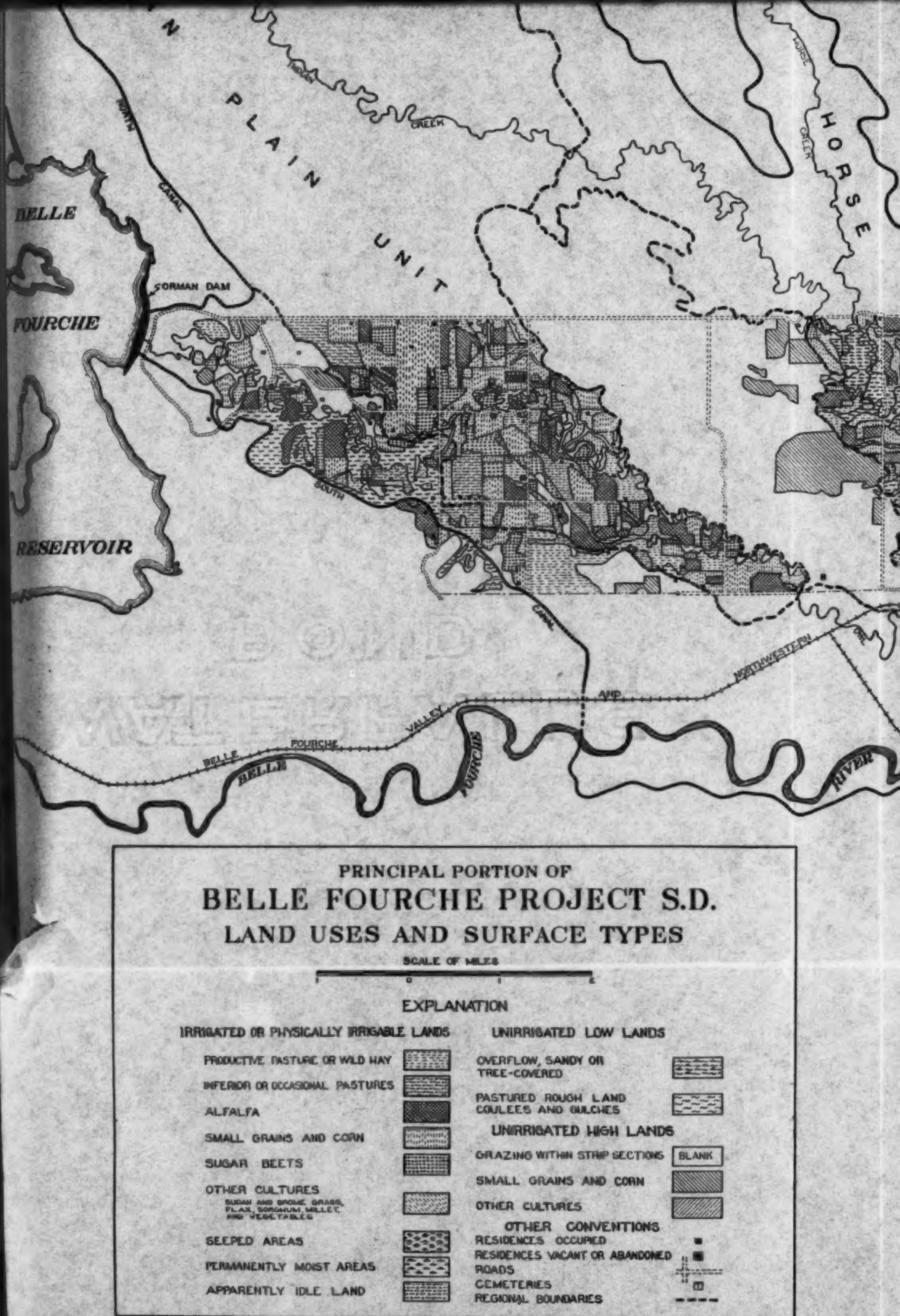
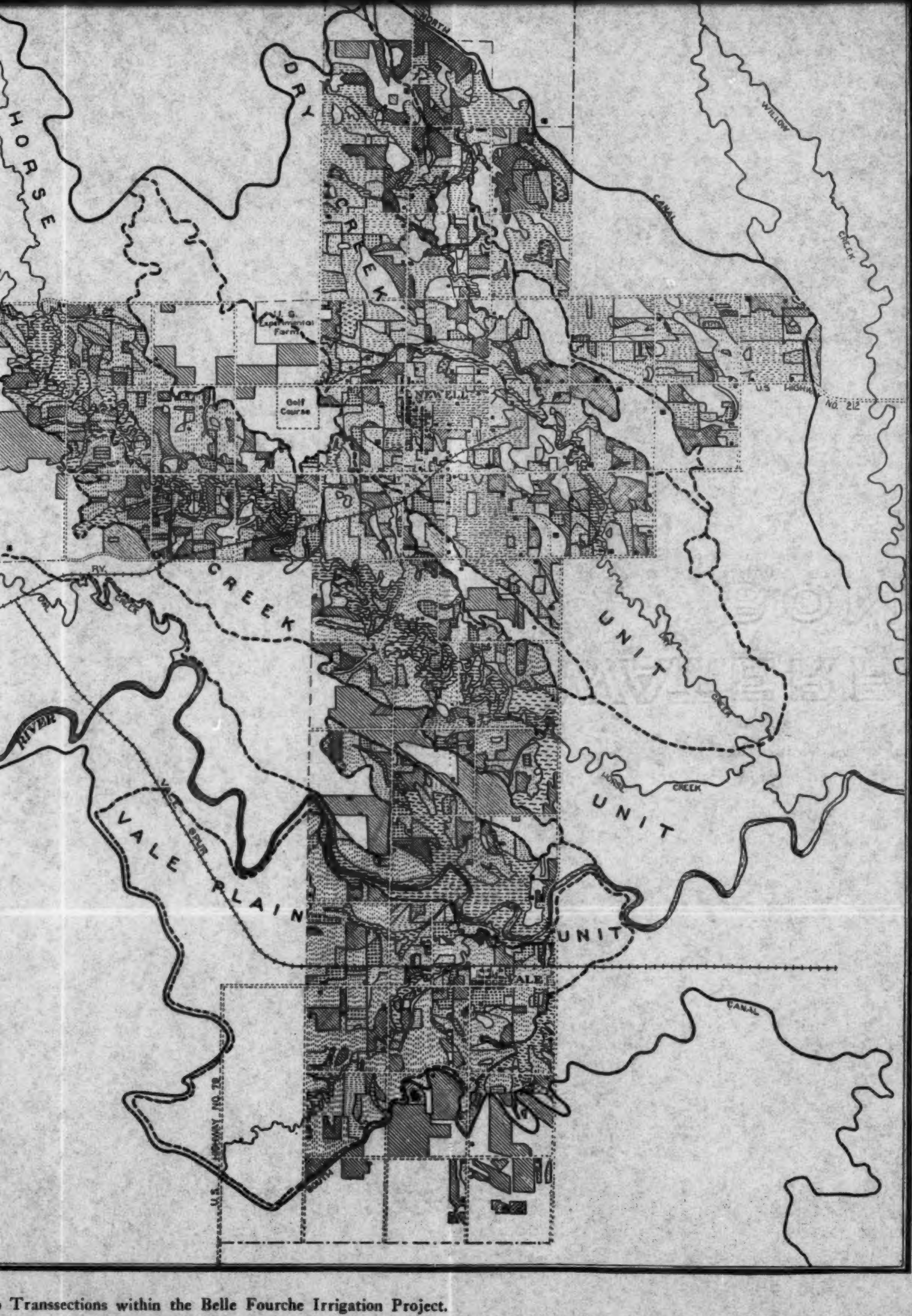


FIG. 10.—The Land Uses and the Surface Types of Two Transsect



Transsections within the Belle Fourche Irrigation Project.

region is clearly set off from its surroundings by higher unirrigable lands but the actual differences in elevation are so slight and the region is so broadly undulatory that its true topographic character is likely to escape detection. Immediately to the west of Dry Creek and roughly paralleling its course lies a discontinuous line of long narrow hills within the larger basin occupied by Dry Creek. These unirrigable heights nearly join at their north and south extremities with the ridge forming the western boundary of the Dry Creek Unit. In the approximate center of the elliptical lowland thus formed is located the village of Newell.[17] Most of the region is "under" two main laterals—Townsite and Deadman—which wind in the familiar fashion along the higher ridges from the North Canal and whose distributary laterals and ditches ramify to all the lower irrigable lands.

The village of Newell differs from Vale, Nisland and Fruitdale, the other villages within the project, in being to some degree a "made town". The village occupies a small portion of an official townsite set aside for urban purposes at the inception of the project. As at first planned the townsite included 960 acres, an area finally reduced to 600 acres; presumably ample space for an American town of 4000 people. Even though its site was deliberately selected, it seems to possess no unique qualities other than that it is well above the level of Dry Creek and its eastern (unoccupied) portion commands as attractive a view as the region round-about affords. Its situation was partially determined by the site of the older town of Vale, for the authorities believed it undesirable or unnecessary to have villages spaced nearer than six miles.

Soon after the selection of the townsite a railroad was built into the region from Belle Fourche but the line terminates a half-mile south of the village. Even the setting aside of a convenient (now idle) strip of land within the townsite was apparently insufficient inducement to build the railroad into the village. In fact most of the Newell townsite is used for purposes other than those envisioned by its creators. Infiltration of settlers into the project did not long continue with the vigor promised by the first few years, probably because experience proved that forty-acre plots were not sufficient in size, in this region, for individual farms.

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[17]So named after the late irrigation engineer and vigorous advocate of dry land reclamation in western United States.

The village now occupies but a fifth of its official area and, seemingly in complete disregard of original plans, a part of the village extends beyond the south limits of the townsite.

The village as a whole, despite its planned character, closely resembles the unifunctional trading centers usually encountered in the western Great Plains. Newell, with a population of less than 500, consists of about one hundred homes located to the west of its two and one-half blocks of unimposing store buildings which [illegible] the main north-south highway. The modest proportions of the village do not provide an entirely accurate measure of the regional importance of this trading center. Intermingled with the ordinary stores common to any center and at a distance grouped at the rail terminus, are structures in which trading of larger significance is carried on. In the rudimentary commercial core is one large mercantile company drawing trade from an extensive territory, and dairy plants to which milk is daily brought from the eastern part of the project. At the rail terminus are grain elevators, pens for stock awaiting shipment and sheep sheds. The latter (partially destroyed by a tornado in August, 1932) especially are of significance, for Newell is a center, secondary to Belle Fourche City, to which sheep and wool are brought, not only from the project but from all the steppe lands from as distant a point as Hettinger in North Dakota. Parenthetically, the Belle Fourche Project ranks second only to the Milk River Project (the leader) in numbers of sheep wintered in all federal projects.

Culturally, the landscape of the Dry Creek Unit is a complex wrought by the incomplete encroachment of tillage under irrigation upon the lands of a comparatively isolated locality traditionally pastoral in character. This is largely true of the project as a whole which is encompassed by a vast region still dominantly pastoral; an especially important concept because the economy of the project articulates to a great extent with that of its surrounding regions. An intricate mosiac of small, irregularly shaped fields in various crops intermingles with irrigated and unirrigated pastures, or perhaps surrounds extensive tracts obviously abandoned following a period of former use. The fact of former use is made occasionally evident by derelict residences and other structures within such areas.

In the cropped fields the dense green of the alfalfa predominates, a measure of the relatively great importance of stock raising; secondarily occur fields of wheat, barley and oats, the two latter

crops being raised in part for hay and fodder for winter stock feed. Still less numerous, but receiving attention disproportionate to their areas, are fields of sugar beets, potatoes and cucumbers, all in small, scattered patches in better soils. The small acreage of sugar beets in the Dry Creek area undoubtedly reflects the unfavorable texture of the Pierre Clay soil for this crop. About 3000 sheep are maintained on twenty-five farms in this unit; these are largely pastured on the surrounding steppe lands in the summer. Ten of the farms maintain beef cattle totalling about 400 head. More widely scattered but in smaller herds are dairy cattle, about 500 head being distributed among forty different farms.

Within the Dry Creek Unit are to be seen the vicissitudes to which a region of poor natural drainage is subject in the later stages of successive years of irrigation. Evidences of poor drainage existed before the period of irrigation; especially was this true just southeast of the townsite where lay a large pond, since drained. Early residents state that in pre-irrigation days there were many sloughs and draws containing stagnant water during the wet weather. Following 1910, when irrigation had gotten into full swing, these low places were convenient sinks for unused or excess irrigation water and many became pond-like as they are to this day. At the same time, but less obviously, the soil locally began to show the ill-effects of excess water. To use a homely and descriptive expression, the land began "to go seepy". The naturally heavy clay soil became increasingly unmanageable, alkali spots appeared, and the cropped portions of the affected fields shrank from the seeped area. Some land was completely abandoned, and in 1928 was begun an extensive drainage program whose features have already been described. As a result much of this land is not now irrigated, though still physically irrigable and having facilities for irrigaton (Fig. 11). The least affected areas to the north and south of Newell are occasionally planted to crops, but for the most part such areas, for want of a better use, merely furnish pasture for a few head of cattle or horses, if the proportion of weeds to grass is not too high, pending the time when it is hoped the seeped condition will have been corrected. The process of complete recovery, however, is a very slow one.

HORSE CREEK UNIT

The narrow valley of Horse Creek, surfaced with the lighter, more manageable Pierre Clay Loam, is more fully utilized than

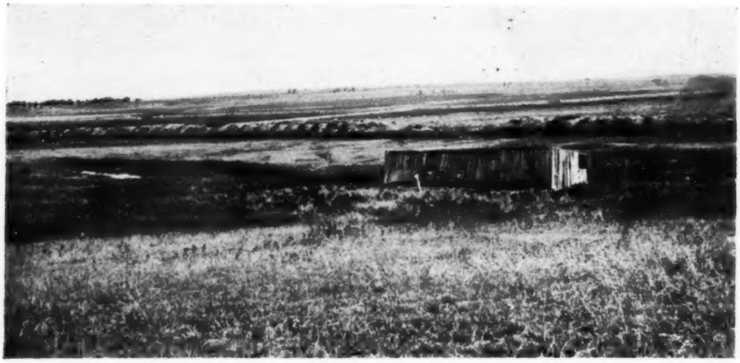

FIG. 11.—Overlooking the seeped area southeast of the Newell townsite, formerly the site of a wet-weather pond. In the middle distance a system of drains is shown, some of which furnish drainage for areas not shown in the view. Patches of tilled land occur within the seeped area which, as a whole, is virtually abandoned; in the far distance well-drained irrigated land is shown. The ruins are characteristic of seeped areas.

the Dry Creek area. In general pattern it resembles the region already discussed; hay and fodder crops predominate because of the pastoral economy of the region. The luxuriant mats formed by fields of sugar beets are larger and more conspicuous than in the Dry Creek Unit, except in the northern portion of the valley

FIG. 12.—The valley of Horse Creek is characterized by gently sloping hillsides surfaced with clay-loam soils. The incised and winding creek is clearly outlined in the view by the cottonwood trees which mark its course. The farmstead shown is one of the earlier ranches north of the Belle Fourche River.

where the loamy soils are displaced by the unfavorable Pierre Clay. Sheep are maintained in larger flocks and by a greater number of farms than in any other equal area of the project. This may be in part accounted for by the availability on every hand of large areas of steppe above the laterals, which provide reasonably dependable summer pasture for the animals while irrigable lands are being cultivated for fodder crops to feed them in the winter. This explanation finds support in the very location of farms maintaining sheep, especially the larger herds. Such farms are marginal to the broad areas of steppe separating Horse from Owl Creek; farm boundaries in such sites extend across the highest canals to include extensive tracts "up in the dry", again using a local expression.

Surface and sub-soils provide better drainage than in the Dry Creek Unit, and consequently but few seeped areas mar the landscape (Fig. 12). Interesting changes have been brought about in the natural drainage lines, however, a condition prevailing also in many of the other creeks. Horse Creek has recently been rejuvenated. High under-cut banks occur along its intricately meandering course, the steep banks of clay and shale being preserved only at the expense of undermining and loss of useful land. The cause of rejuvenation is to be found in the new function of the creek as a waste-way for unused irrigation and drainage water.

Horse Creek Unit, with no trading center within it, is commercially allied to the Newell area.

THE ARPAN PLAIN

West of the Owl-Horse Creek divide lies the broad lacustrine plain which extends to the western limits of the project, here called the Arpan Plain. This flat-lying land is strikingly revealed in the culture-pattern, making it possible to discern in the pattern the limits of the plain as it breaks into the sloping land of Owl Creek. The irrigation laterals here run straight for long distances, usually paralleling roads and fence-lines down the eastward slope of the plain to the shallow trench formed by Indian Creek. The farm laterals also depart from the contour-like course normal to the project, with the result that the fields represent many kinds of geometrical figures.

Of all parts of the Belle Fourche Project, this one is apparently the most suited to irrigation agriculture and was, in fact, the first unit to be provided with such facilities. The utilization of the

plain does not, however, reflect the degree of superiority which might be expected in view of these circumstances. Sugar beets, which usually mark the better lands, are not common in the plain, except toward its southern margin: the structure of the Orman Clay resembles too closely that of Pierre Clay.

Nearly a fifth of the plain is today unproductive, owing to farm abandonment following wide-spread seepage. The largest continuous area of seeped land in the project occurs on the western margin of the plain under the North Canal. It was observed that seepage has been especially destructive here not only because of many years of seepage from the great canal of the project, but because impervious shale lies very close to the surface (Fig. 13).

FIG. 13.—A seeped portion of the Arpan Plain, showing characteristic surface and cottonwood trees marking the site of a lateral. The soil is very shallow here and is underlain by impervious shale, resulting in poor drainage.

In order to drain the seeped lands in the western part of the plain, virtually a new creek, draining to Owl Creek, has been added to the landscape; in reality an artificial drain, it is nevertheless known by many as Sumptive Creek.

Beyond the seeped lands, which are today idle, the land is used for pasture and those crops common to the project. Several large sheep and cattle ranches are scattered over the plain. Commercially the region faces southward to Nisland, a small village on the railroad, and westward to the city of Belle Fourche.

VALE PLAIN

The Belle Fourche River, owing to the width of its flood-plain and the height of its north bluff (which has discouraged bridge-building except on the main roads) forms a definite line of demarcation of the Vale region from the areas to the north of the river. The flood-plain is not significant in the economy of the region. The narrow terraces which border it present a striking contrast to the largely unutilized bottom lands, for the terraces are irrigated by water led down the hundred-foot north bluff by pipe-line.

South of the river there is no corresponding high bluff; instead the limit of the flood-lands is marked by a bank perhaps twenty-five feet in height. From this bank to the South Canal the surface is a gently rolling to flat plain which is here called the Vale Plain. The village of Vale, located toward the eastern margin of the plain, has about half the population and housing equipment of Newell, to which in appearance and functions it is quite similar.

As a whole the Vale Plain is the most closely utilized section of the project. This is seen in the extent to which the more favored crops predominate as well as in the greater number of houses per section of land. Sugar beets are an important crop in the plain, as they are in other sections south of the Belle Fourche River. This has led to a somewhat denser Mexican population here. Probably this greater production of sugar beets is a measure of the more favorable texture and structure of the Vale series of soils for this crop. Beet dumps occur at various points along the railroad, the sugar factory being located on the eastern outskirts of the city of Belle Fourche. Cucumbers, produced widely in small fields, are brought to the pickle vats near the railroad station at Vale. Sheep and cattle are owned in small flocks and herds by a large proportion of the farms; this is an industry not so highly localized as in other units of the project, but rather is an adjunct to general farming.

The landscape as a whole presents a pleasing appearance but is occasionally marred by seepage and by drains whose embankments are exceptionally high owing to the depth of the shale. Seepage has reduced considerably the productive area but the proportion of irrigated land to total land is still higher than in other areas of similar size in the project.

INCLUDED AND SURROUNDING STEPPE

Innumerable areas of dry steppe of small extent rise above the lowlands in all parts of the project except the Arpan Plain. Such areas are likely to form essential elements in the regional economy: here providing additional pasture for horses, cattle and sheep, there furnishing desirable sites for farmsteads, elsewhere being used for dry farming. Often the latter use makes difficult the mapping of the exact limits of irrigated areas, because an entire slope planted to one crop may present, in a year of favorable rainfall, no visible difference between the dry-farmed and the irrigated portions.[18]

The larger included bodies of high steppe are not officially considered to be within the project but these, like the smaller areas, must be regarded as being supplemental to the irrigable lands. Although rarely sites for farmsteads, nearly all such land is in farms and strictly waste land is rare indeed. Such small parts of it as do not furnish summer pastures are used for dry-land farming. In crossing the highest laterals into the unirrigated lands there is usually an abrupt change in the cultural landscape, which is molded upon much simpler lines than that of the irrigated lands.

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[18]Not uncommonly grains are raised on irrigable land without resort to irrigation in years of maximum or near-maximum rainfall. For example, in the crop season of 1932 much of the barley crop was "made" without irrigation on irrigable lands. By and large successful *diversified* agriculture is made possible here by irrigation, although during seasons of above-normal rainfall this fact is not sufficiently realized. Given a succession of such years many still unconvinced pre-irrigation settlers find support in their frequent observation that "the project should never have been put in". Undoubtedly this circumstance, together with the increasing area of seepage and a poor assortment of settlers, occasioned the proposal by Congress to abandon the project in 1920. The project director has this to say with regard to settlers before 1920: "About 37,000 irrigable acres of public land were entered for the most part by people who had no foundation for an agricultural life and were particularly unsuited to the trials of irrigation farming, and who as a rule had no intention of becoming farmers. Business and professional men, clerks, school teachers, preachers, and plumbers all considered it genteel to own an irrigated ranch and although disappointments came early they nevertheless considered that speculative possibilities would more than balance the lack of profitable production." (*New Reclamation Era*, October 1927, p. 147). I would amend Mr. Youngblutt's first sentence to read: "had no intention of becoming farmers and little experience in stock raising in irrigated areas". I am in agreement with the project director in the belief that twenty or twenty-five years is insufficient time to prove or disprove the success or failure of the Belle Fourche Project.

Few of the roads have been continued through the inter-stream areas and large parts remain unfenced. Artificial drainage lines do not interfere with conformation of cropped land boundaries to the rectangular pattern of the survey. Thus the crops, almost exclusively barley, wheat, oats, and corn, stretch like great blankets of forty, eighty or more acres in extent. Preceding the harvest the golden yellow of the ripened grains relieves in a pleasing fashion the monotonous brown of the short grass on the higher slopes of the hillsides. In the route of the east-west trans-section (Fig. 10), just above the irrigated land of Horse Creek, was encountered the largest single field in any one crop—a 330-acre field of barley, possibly the largest in the project. The absence of fallow fields is a departure from the usual cultural scene in dry-farming regions.

The included areas of steppe represent on a small scale the landscape of the lands surrounding the project in all directions. The dry-farmed land beyond the South Canal provides a transition rather than a complete break from the irrigated lands to the surrounding, unmodified steppe. Here, along the main roads, are a number of dry-land farms and farmsteads, but only two miles beyond the South Canal the cropped land suddenly disappears and is replaced by the unplowed short grass of the high ridge overlooking the project. To the east and north of the project, on the other hand, crossing the canal means an abrupt replacement of verdant farm lands by extensive, nearly uninhabited grazing lands. Almost every sign of the rapid settlement of these dry lands from 1910-12 is now effaced. Where, in those fairly recent times, there were numbers of claim shacks on homestead quarter-sections, there is now scarcely a habitation and seldom a fence. These comments apply specifically to the region adjacent to the North Canal and extending therefrom to the Moreau River where occasionally dry land ranches are again to be seen. The adjacent steppe provides additional pasture for project livestock and thus the dry steppe articulates in function with the irrigated lands.

That a study of the Belle Fourche Project should begin and end with the steppe lands so recently invaded by irrigation seems entirely appropriate (Fig. 14). Pastoral activities form the major elements in the cultural landscape of the project; this was its cultural heritage from the past. The great areas of pasture, the dependence of dry grazing lands, the reaping of wild hay from

every available locality, the large areas planted to alfalfa, the cereal crops of barley, oats and corn often grown for additional fodder and forage, the ubiquitous hay-stacks, the herds of cattle and horses and still larger flocks of sheep in the fields and in the surrounding steppe under the care of shepherds—these features correctly record in the landscape the essential character of the Belle Fourche Project.

FIG. 14.—A half-mile beyond the North Canal looking east toward a ridge studded with tepee buttes. This is typical range land but, except for altitude, differs in no essential way from the bulk of the irrigated land within the project.

The Railway Traverse as an Aid in Reconnaissance

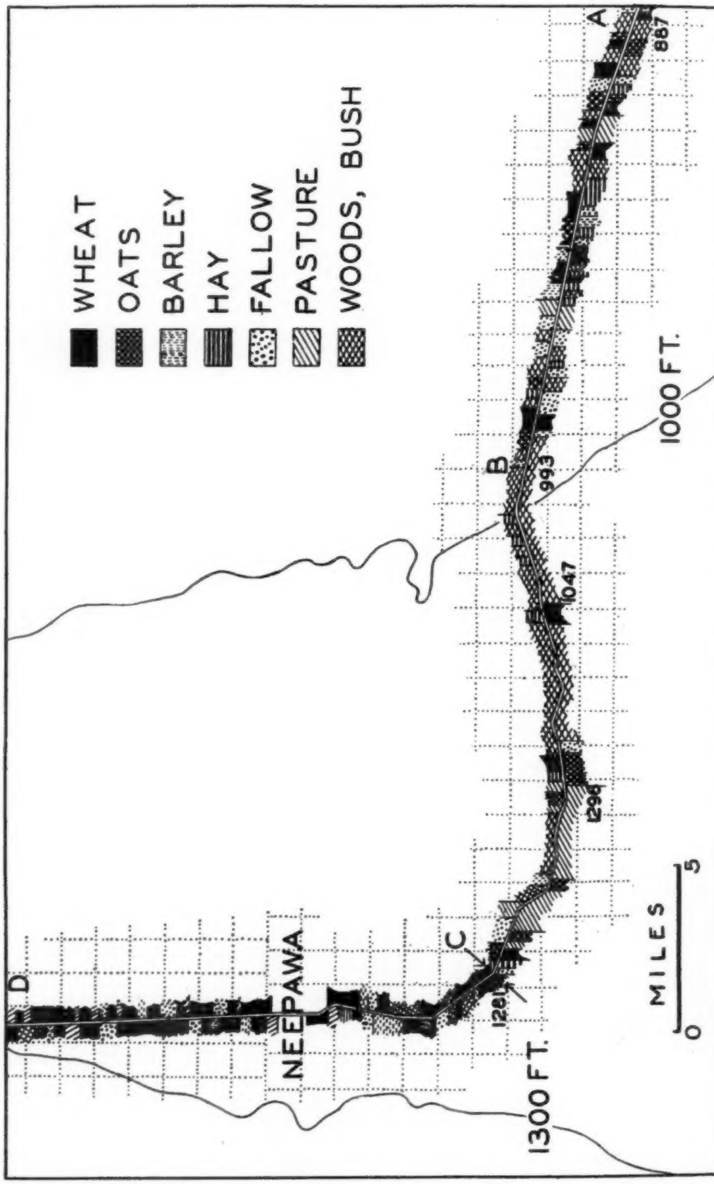
CHARLES C. COLBY

The railway traverse, as illustrated by the accompanying examples, represents an attempt to secure quantitative data in regional reconnaissance. The underlying idea is to record on a base map of the area traversed, what one sees from the car window and thus to provide tangible materials for future study. It is hoped that such traverses may prove to be a step in the solution of the dual problem inherent in regional work, namely, accuracy on the one hand, and reasonable coverage on the other.

The accompanying traverses (Figs. 1 and 2) are small sections of a railway traverse from Winnipeg, Manitoba, westward via Prince Albert, Saskatoon and Edmonton to Grande Prairie in the Peace River section of Alberta. They were made in August 1929 by a graduate field party from the University of Chicago.[1] The traverse in Figure 1 lies in a well-settled area long the Neepawa-Riding Mountain division of the Canadian National Railways. Its eastern end is about 80 miles west of Winnipeg. The one in Figure 2 is in the Peace River country, a pioneer area about 250 miles northwest of Edmonton. The observations recorded in these traverses were preceded by some preparatory ground study in which the party became familiar with the base maps with which they were to work, with the size and shape of the fields and other features of the cultural pattern not shown on the maps, and with the appearance of the major crops in August.

Traverse records in Western Canada are facilitated by excellent base maps. Practically the entire settled area is mapped on the scale of 1 to 190,080 or 1 inch to 3 miles. The maps are of recent date and the cartographic work is of high order. This means that the maps present the major items in the landscape pattern as it is today. As each map covers an east-west distance

[1]The party included W. J. Berry, H. C. Minton, John Morrison, Paul Post, George Primmer, Leavelva Bradbury, Mabel Crompton, Mary McRae, Myrtle Nelson, Marie Peterson, Marguerite Uttley, and the writer. Henry M. Leppard accompanied the party as a guest member under the Salisbury Fund.



WHEAT
OATS
BARLEY
HAY
FALLOW
PASTURE
WOODS, BUSH
A
887
B
993
1047
1000 FT.
1290
C
1281
D
NEEPAWA
1300 FT.
MILES
0
5

Fig. 1

FIG. 1.—Traverse covering 46 miles along the line of the Neepawa-Riding Mountain division of the Canadian National Railways. The eastern end of the traverse, marked A, begins at the station of Katrine. B and C indicate the stations of Berton and Hallboro respectively, while D marks the northern end of the traverse. The dotted grill shows the section lines. The numbers immediately below the traverse indicate elevations above sea level. The numbered lines are contours.

of approximately 95 miles, and as the scale is relatively small, frequent changes of maps in making a railway traverse are not necessary. Figure 1 was made on the Brandon sheet (Sectional Map No. 72), while Figure 2 was made on the Dunvegan sheet (Sectional Map No. 462). For the sake of clarity in reduction, most of the features shown on the maps were omitted in making the drawings for these traverses. To get the full setting for the traverses, readers should consult the sheets indicated. The sheets are printed in the office of the Surveyor General at Ottawa.

In making these traverses the party worked in teams of two, two teams working at a time. One of the teams made a record from the right-hand windows, while the other team worked the left-hand side. As the work requires a high degree of concentration, better results were obtained when the teams worked for intervals of about an hour rather than for longer periods. In order that each team begin its work at a known point, team changes

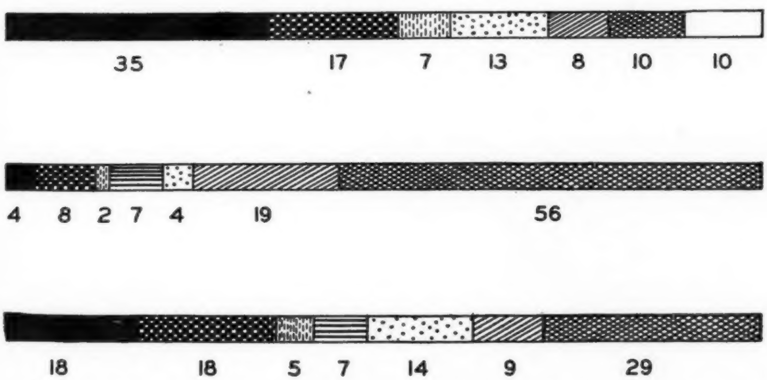


FIG. 3.—Relative importance of each cover item in three sections of the traverse shown in Figure 1. The lower bar is for the 14 miles from A to B, the middle bar for the 16 miles from B to C, while the upper bar is for the 14 miles from C. to D. The vacant space in the upper bar shows the percentage of the total frontage occupied by the village of Neepawa.

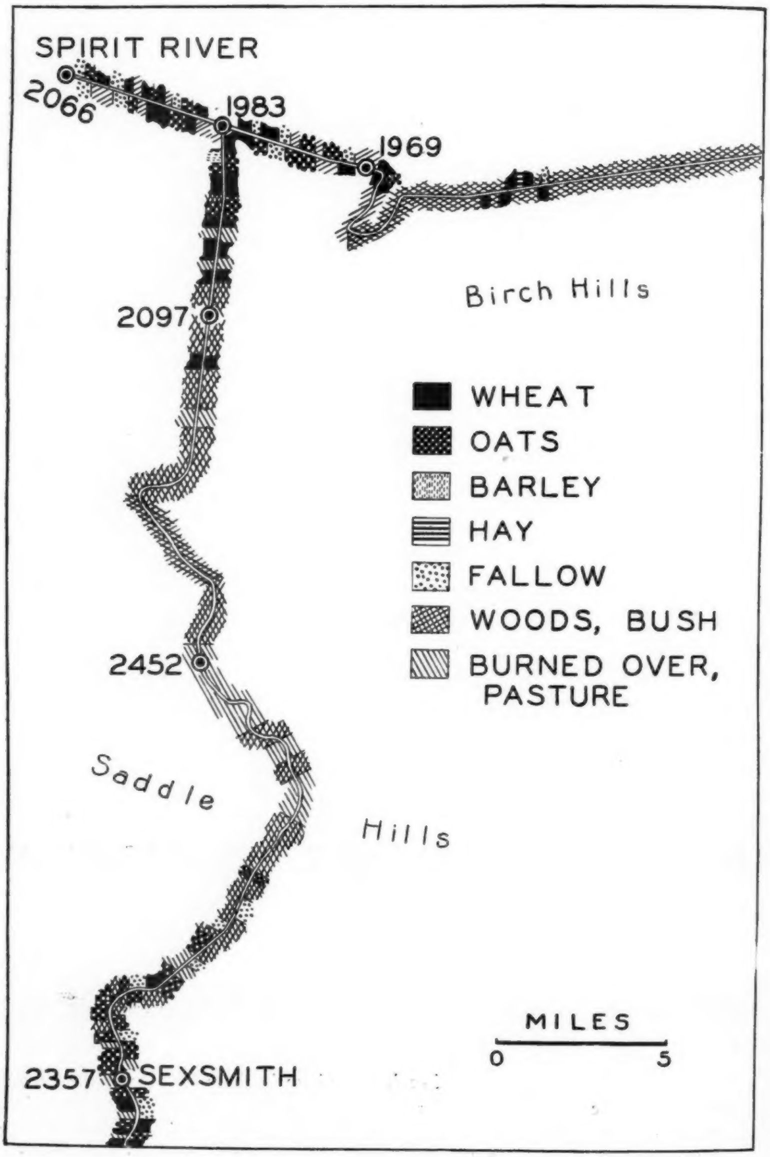

SPIRIT RIVER
2066
1983
1969
Birch Hills
2097
WHEAT
OATS
BARLEY
HAY
FALLOW
WOODS, BUSH
BURNED OVER, PASTURE
2452
Saddle
Hills
MILES
0
5
2357
SEXSMITH

Fig. 2

FIG. 2.—Traverse in the Spirit River section of the Peace River country. The numbers show elevations above sea level. The railroad was built into the area from the east and originally extended only to Spirit River. Later it was continued southward but because of steep slopes south of Spirit River it was built from Rycroft, the station at elevation 1983.

were made at stations. The precise method of work varied with the teams. Commonly, however, one member of a team made the observations while the other member recorded them on the map. The observer identified the crops or other items of the cover and measured the frontages occupied by each crop or item along the railway. Distance was measured by counting the telephone poles, the count being made with a pocket tallying machine (Keuffel & Esser Co., New York), such as is used in ground pacing. In the prairie sections of Canada, the telephone poles are spaced regularly and give a fairly accurate means of measuring distance. The task of recording the frontage occupied by a particular crop was facilitated by the fact that the section lines appear on the base maps, and that the fields in most places are even divisions of the section. The record on the map was made in a color code. As stations are spaced about every five miles along the railways, the spacing could be checked before errors became serious. During the pause at a station, notes covering points of special interest in the preceding miles were recorded on the map. Briefer notes were made en route as striking changes in slope, drainage, and the like appeared.

The traverse in Figure 1 reveals three distinct cover combinations, or, in fact, three types of land use. The first cover combination is characteristic of the 14 miles of the traverse extending

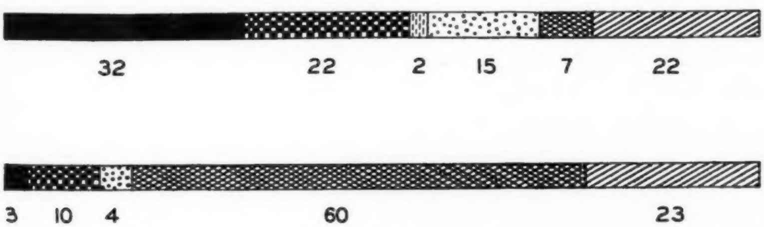


FIG. 4.—Relative importance of each cover item in two sections of the traverse shown in Figure 2. The lower bar is for the 28½ miles from Sexsmith to the station at elevation 2097. The upper bar is for a distance of 14 miles made up of the 5 miles from the station at elevation 2097 to the station at elevation 1983, plus the 9 miles from Spirit River to the station at elevation 1969.

from A to B. In this section each item of the cover is of considerable importance, the relative importance of each item being shown in the lower bar of Figure 3. Thus wheat, for example, occupies 18 per cent, oats 18 per cent, and barley 5 per cent of the frontage along the railroad in this section of the traverse.[2] Such a linear balance in the crop frontages suggests a mixed type of farming with wheat and oats predominating. The second cover combination occupies the 16 miles of the traverse from B to C of Figure 1. In this section crops are conspicuous by their absence. In fact, the middle bar of Figure 3 shows that in this section woods and bush occupied 56 per cent and pasture 19 per cent of the railway frontage. This woods-pasture combination stands in marked contrast to the combinations in the other sections. The third cover combination extends over the section of the traverse between C and D of Figure 1. In this 14 miles most of the land is cropped, with wheat strikingly predominant and oats and fallow conspicuous (upper bar of Fig. 3). This combination is the one commonly associated with the Canadian Prairies.

The numbers along the traverse in Figure 1 and the two contours reproduced show that the first combination lies in a broadly level area below 1000 feet, the second lies in terrain which rises nearly 300 feet in the 16 miles, while the third lies in an area which slopes less than 20 feet in the 15 miles. These facts of slope are shown more clearly on the base map. Examination of this map shows that each of the three sections of the traverse is a distinctive terrain. Thus the first combination lies on the "first prairie level" or the Plain of Manitoba, the second traverses the hilly slope of the east-facing Manitoba escarpment, and the third is on the "second prairie level" or the Plain of Saskatchewan.[3]

The traverse in Figure 2 gives concrete evidence of the character of the Peace River country, with small cleared prairies set like oases in a vast wilderness of uncleared bush. In the section covered by the upper left hand corner of the figure, most of the land is under cultivation. This section of the traverse lies in

[2]The percentages were obtained by finding for each section the relation of the length of the frontage occupied by each cover item, to the total frontage of the section. The section between A and B of Figure 1, for example, represents 14 miles or a total railway frontage of 32 miles. Of this 32 miles of frontage wheat occupies 5 miles or 18 per cent.

[3]Young, G. A.: *A Descriptive Sketch of the Geology and Economic Minerals of Canada.* Dept. of Mines, Geol. Surv. Branch, No. 1085, pp. 107-8.

Spirit River Prairie—a cleared area of about 170 square miles. Originally some of the cleared area was mantled with grass while other parts were covered with low bush or light timber. The upper bar in Figure 4 shows that in 1929 the cover combination in this area was made up in large measure of four items, namely, wheat, oats, fallow and bush.[4] Spirit River Prairie is surrounded on all sides with typical Canadian bush. Neither the land nor the timber is of good enough quality to warrant the cost and effort of clearing most of these bush covered areas. The continuity of the bush is illustrated by the Birch Hills and the Saddle Hills sections of the traverse. The lower bar in Figure 4 gives the relative place held by each cover item in the 28½ miles between the station at elevation 2097 and Sexsmith. This section of the traverse lies transverse to the Saddle Hills cuesta, the north-facing escarpment of which limits the Spirit River area on the south. In the Saddle Hills area, the land is high and rough, the soils are poor and the few clearings only emphasize the continuity of the bush. Back from the railroad little or no land is cleared in either the Birch Hills or Saddle Hills sections.

Obviously a traverse or log made from a moving train will contain errors. Obviously, also, better results may be expected from slow moving trains which make many stops than from fast moving expresses stopping only at the larger places. In the traverse under discussion it is to be expected that mistakes were made in identifying cover items, for barley and certain types of wheat look much alike in their mid-summer phases and the criteria used in distinguishing pastured area were not altogether satisfactory. Errors in spacing also are inevitable, both from mistakes in measuring the frontage occupied by the various items and in plotting a given frontage on the map. Experimentation and checking, however, have demonstrated that such errors are not serious where the preparatory study is adequate and the work is done carefully. In any case the results should prove far more accurate than conclusions based on uncharted observations of even the most careful and experienced travelers.

The railway traverse has proved its worth in numerous ways. Study of such traverses, for example, raises questions for subse-

[4]A detailed study made by W. J. Berry following the reconnaissance demonstrated that the railway traverse showed striking correspondence to his detailed maps of the area, and to statistics of the Dominion Census of 1926.

quent detailed work in the field. It leads to the formulation of preliminary ideas of crop and cover combinations. It directs attention to areas of unusual interest or perplexity. It offers visual and statistical support to regional generalizations. The traverse may be useful, moreover, in applying the results of a detailed examination of a small part of an area to the whole area. It gives a chance to compare field records, however fragmentary, with statistical materials derived from census or other sources. In short, it is a means, and an effective one, of launching a regional study.

*The Surface Configuration of Southeastern Brazil**

PRESTON E. JAMES

In southeastern Brazil we are dealing with a plateau near the rainy east-coast margins of the low latitudes. In structure, this plateau is composed of a variety of crystalline rocks forming a basement complex, overlain in part by a covering of sedimentary strata, and broken by a complicated system of faults. Stream dissection under tropical conditions of deep rock decomposition has proceeded apparently to the formation of several erosion levels, the most recent of which have been lifted and subjected again to the attack of running water. As a result of the system of faults, and of the differential resistance of the various rocks to tropical weathering, a surface configuration of very great diversity has developed.

The general concept of southeastern Brazil as a plateau tipped gently to the northwest and facing the sea with a steep escarpment, is well known. For a long time, however, writers on the area have recognized that a great variety of detail was awaiting description.[1] It is only recently that the essential arrangement of the surface features has been set forth. The many studies of Derby and Branner[2] laid the groundwork for the more recent investigations[3],

*The field studies on which this paper is based were carried on in 1930 and 1931 aided by generous assistance from the National Research Council and from the University of Michigan.

[1]Among the most valuable works of the earlier period are:
W. L. v. Eschwege, Beitrage zur Gebirgskunde Brasiliens, Berlin, 1832;
R. E. Burton, Explorations of the Highlands of Brazil, London, 1869; and
C. F. Hartt, Geology and Physical Geography of Brazil, Boston, 1870.
See also the very complete list of works contained in:
A. D. Gonsalves, Bibliographia da Geologia, Mineralogia, e Paleontologia do Brasil, Serv. Geol. e Mineral. do Brasil, Bol. 27, Rio de Janeiro, 1928.

[2]Summarized by J. C. Branner, Outlines of the Geology of Brazil to Accompany the Geologic Map of Brazil, Bull. Geol. Soc. Amer., Vol. 30, 1919, pp. 189-338, with extensive bibliography.

[3]Important descriptions of surface configuration are contained in: C. Delgado de Carvalho, Physiographia do Brasil, Rio de Janeiro, no date;
A. B. Paez Leme, Evolução da Estructura da Terra: Geologia do Brasil, Arch. Mus., Nac., Rio de Janeiro, 1924; and
M. Rub, Die Oberflächengestaltung des Brasilianischen Berg- und Taffellandes, Geog. Zeit., Vol. 30, 1924, pp. 264-285.

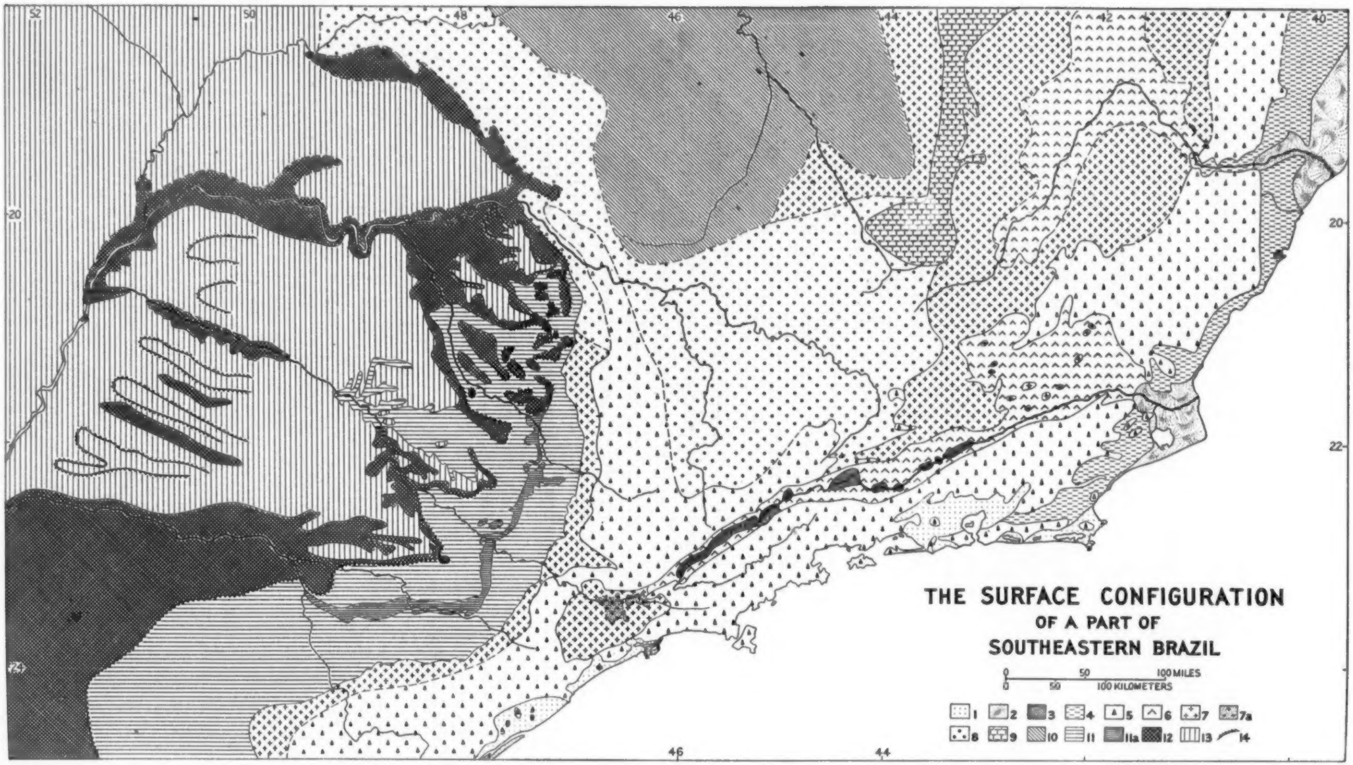

THE SURFACE CONFIGURATION
OF A PART OF
SOUTHEASTERN BRAZIL
0 50 100 MILES
0 50 100 KILOMETERS
1 2 3 4 5 6 7 7a
8 9 10 11 11a 12 13 14
52
50
48
46
44
42
40
20
22
24

Fig. 1.—The Surface Configuration of a Part of Southeastern Brazil. The divisions of this map were established by field reconnaissance. The boundaries were observed at numerous key places and extended by reference to the state topographic and geologic maps listed in footnote 6. The dashed boundaries are approximate. (The map is reprinted from The GEOGRAPHICAL REVIEW by courtesy of the American Geographical Society, New York.)

KEY:

1. Coastal lowlands or *baixadas*.
2. Deltas of the Rio Parahyba and Rio Doce.
3. Flood plain basins of the middle Parahyba.
4. Coastal hilly and terrace belt.
5. Crystalline Mountains.
6. Lower Crystalline Plateau (500m.), and the Parahyba Valley.
7. Intermediate Crystalline Plateau (800m.).

7a. Sao Paulo Basin, lacustrine deposits.

8. Higher Crystalline Plateau (1,000—1,100m.).
9. Serra do Espinhaço
10. Tablelands of older sedimentary rocks (mostly early Paleozoics) —São Francisco Basin.
11. Permo-Triassic Inner Lowland of São Paulo.

11a. Tatuhy formation.

12. Diabase areas.
13. Jurassic-Cretaceous tablelands of western São Paulo.
14. Cuesta and mesa scarps of São Paulo.

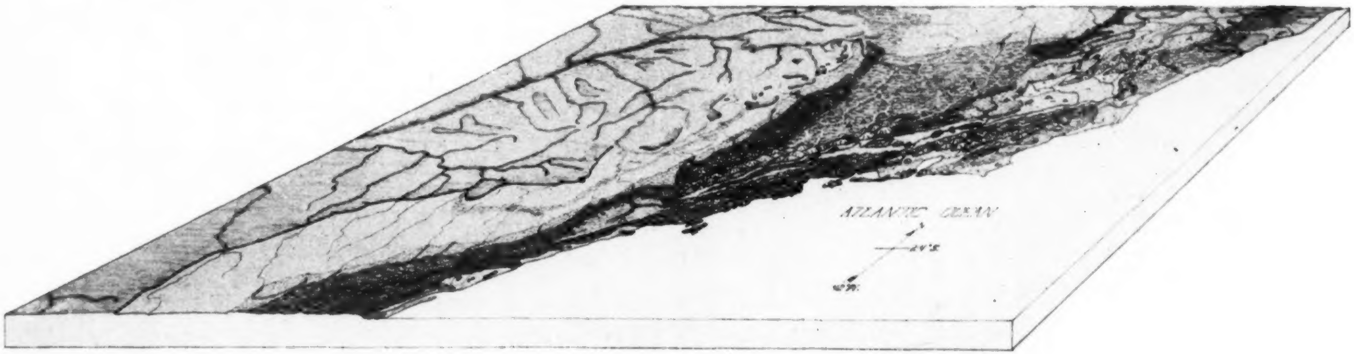


Fig. 2.—Generalized Block Diagram of the Surface Configuration of Southeastern Brazil.

—Drawn by Dr. R. M. Glendinning

notably by Maull[4], and von Freyberg[5], who presented in fundamental outline, the arrangement and structural relationships of the surface features which make up the plateau and its margins. The present map of surface configuration (Fig. 1) introduces certain refinements of detail made possible by field work and by the recent publication of several important geologic and topographic maps in the states of São Paulo and Minas Geraes, and in the Federal District.[6]

From an examination of the map (Fig. 1) it may be seen that southeastern Brazil is composed of four chief parts. The most conspicuous features are the ranges of crystalline mountains which form an up-standing rim to the plateau, with few interruptions, from southern Brazil northward beyond the limits of this study. While from certain aspects these ranges have the subdued massive form of old mountains, the sea-facing escarpment, some 800 meters high, which they surmount is sharp and youthful. Then there is also the Serra do Espinhaço which extends from central Minas Geraes northward into Bahia, standing abruptly above the crystalline plateaus about it (Figs. 2 and 3).

The crystalline plateaus, the second major division of the area, lie inland from the rim of crystalline mountains. Three distinct plateau areas lying at different elevations are distinguished and recognized on Figure 1. The highest plateau is about 1,000 to 1,100 meters above sea level; the intermediate plateau is about 800 meters; and the lower one is about 500 meters. In geologic structure and physiographic history, as well as geographic arrangement, these plateaus are intimately related to the crystalline mountains.

[4]O. Maull, Die Geomorphologischen Grundzüge Mittelbrasiliens, Zeit. der Gesel. für Erdk. zu Berlin, 1924, pp. 161-197;

idem., Die Landschaften Mittelbrasiliens, Ergebnisse einer Forschungsreise (1923), Ver. des Deutschen Geographentages, Vol. 21, 1926, pp. 62-71;

idem., Vom Itatiaya zum Paraguay, Ergebnisse und Erlebnisse einer Forschungsreise durch Mittelbrasilien, Leipzig, 1930; and

P. Denis, Amérique du Sud, in "Geographie Universelle," Paris, 1927.

[5]B. v. Freyberg, Ergebnisse geologischer Forschungen in Minas Geraes (Brasilien), Neues Jahrbuch für Mineral., Geol., und Paläontologie, Sonderband II, Stuttgart, 1932, containing a bibliography of nearly a thousand titles.

[6]Estado de São Paulo, Commissão Geographica e Geologica, Carta Geologica do Estado de São Paulo, São Paulo, 1929; and several new sheets of the topographic map, scale 1/100,000;

Estado de Minas Geraes, Commissão Geographica e Geologica, Bello Horizonte, several new sheets of the topographic map on the same scale;

Serviço Geographico Militar, Carta do Districto Federal, Rio de Janeiro, 1922, scale 1/50,000.

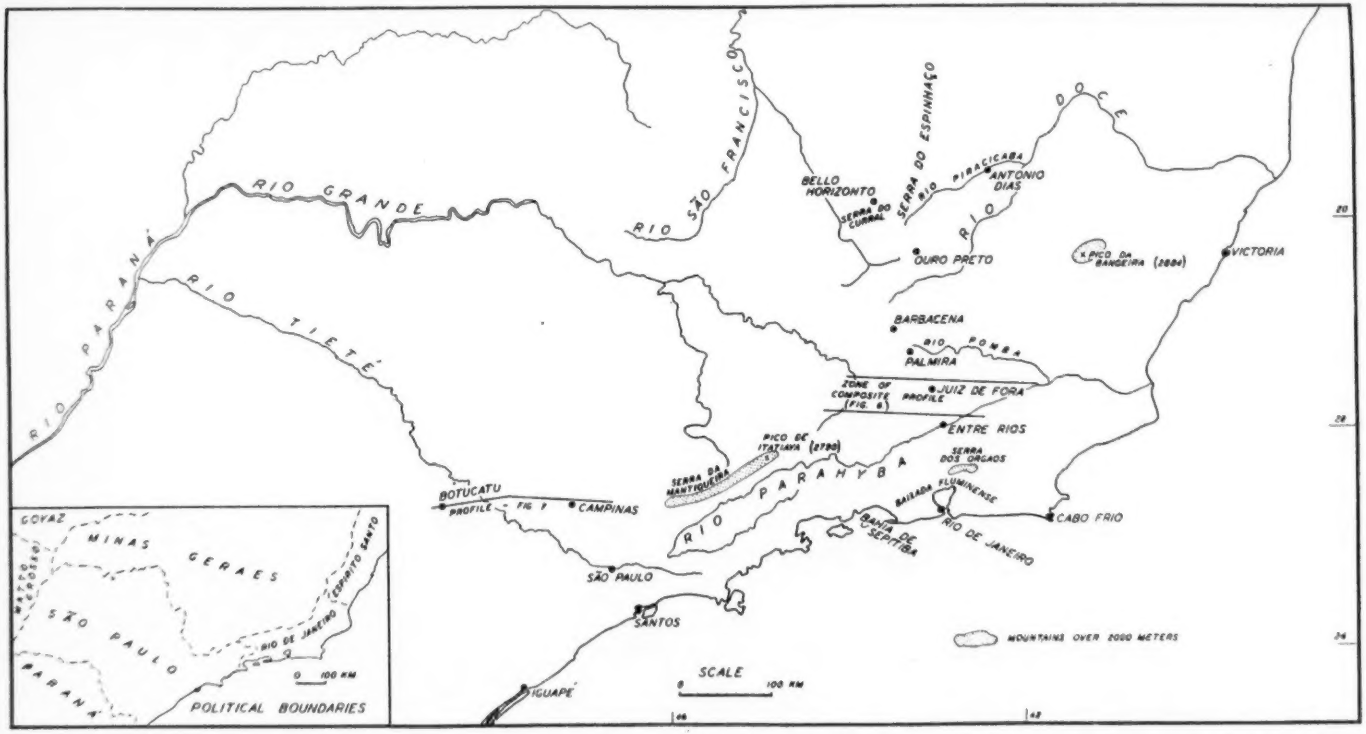


FIG. 3.—General Location Map for Southeastern Brazil including position of mountain areas over 2,000 meters, and the location of the profiles.

The third general division of southeastern Brazil includes those parts occupied by stratified rocks, mostly sedimentary. The southern end of the São Francisco Basin appears in the north, composed of nearly horizontal early Paleozoic limestones. More recent formations, from Permian to Cretaceous, are represented in the Paraná Basin of western São Paulo, Minas Geraes, and the state of Paraná. In this area the flows and sills of diabase are included among the various strata which dip gently toward the Paraná River.

The fourth general division of the area is the coastal zone. This is composed of deltas, marine terraces, and previously drowned, now partly raised lowlands.

THE CRYSTALLINE MOUNTAINS

The margin of the plateau in southeastern Brazil is composed of a number of ranges of block mountains which rise, in most places steeply, from the inner edge of the coastal zone. Especially south of the Rio Parahyba they present toward the sea a striking escarpment only slightly notched by youthful streams. North of the Parahyba Delta, in the state of Espirito Santo (Fig. 3), the sea-facing scarp is not so abrupt and is breached by a number of valleys which head back into the mountain block. However, the rim of the plateau is broken by only two valleys which lead through the mountains to the interior. These are the valleys of the Rio Doce and the Rio Parahyba. Elsewhere, to cross the mountains it is necessary to climb more than 450 meters, and generally more than 800 meters to reach a pass (Fig. 2).

The dominant features of these mountains are related to two major systems of faults. Structural valleys and block ranges, north of Cabo Frio, lie parallel to faults running in a north-northeast to south-southwest direction. Similar structural forms in São Paulo state correspond with a fault system running east-northeast to west-southwest. In Rio de Janeiro state these two systems of faults cross each other at an oblique angle, thus creating a series of block mountains of sub-rhombic form, bounded by angular valleys.[7]

[7]O. Maull, Vom Itatiaya zum Paraguay, loc. cit., p. 314ff.

See also: C. M. Delgado de Carvalho, Physiographia do Brasil, loc. cit.; and

G. R. Sturzenecker, Contribuição para o Estudo da Orographia Brasiliera, Proc. 2nd Pan Amer. Sci. Congress, 1915-1916, Vol. 2, Sec. 2, Washington, D. C. 1917, pp. 310-318.

However steep and abrupt may be the sea-facing side of these several mountain ranges, as a whole they exhibit the massive, rounded outlines of old mountains, in many respects suggestive of the southern Appalachians when viewed from a distance. They are almost entirely forested and mantled with soil. Bed rock exposures are not common, even on the steep front toward the sea. Only the highest ranges raise rocky needles to a jagged sky-line. Three ranges alone surpass the tree-line, which lies about 1,900 to 2,000 meters above sea level. These are the Serra da Mantiqueira in southwestern Minas Geraes (Fig. 3); the Serra dos Orgaos, overlooking Guanabara Bay north of Rio de Janeiro; and the mountains along the border of southern Espirito Santo and Minas Geraes which culminate in the highest peak in Brazil, the Pico da Bandeira (2,884 m.).

Erosion Levels in the Crystalline Mountains.—Except for these highest peaks, the summits are conspicuously rounded and even. A number of well-developed levels occur, which have been interpreted as the now-dissected remnants of former baselevel surfaces.[8] The existence of these erosion surfaces was recognized by some of the earliest writers on the area.[9]

The highest of these levels, however, is of considerable importance because of the possibility that it may have been formed as a high-level denudation surface. It is well developed about 200 meters above the tree line in the three mountain ranges which attain this elevation. Even though the rock in all three cases is crystalline (on Pico do Itatiaya in the Serra da Mantiqueira, Fig. 3, a nepheline syenite) typical lapies and other forms of rapid solution have been produced above the tree line, but in no cases below it.[10] The rapidity of denudation in these places unprotected by the thick covering forest may possibly have resulted in the formation of a high altitude denudation level—a gently rolling surface composed of rocky ridges and waste-filled hollows. These localities are critical for the investigation of this problem.

However, the same interpretation could not be applied to the lower levels which may be discerned in these mountain ranges.

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[8] O. Maull, Vom Itatiaya zum Paraguay, loc. cit., p. 55.

[9] M. Pissis, Mémoire sur la position géologique des terrains de la partie australe du Brésil, et les soulèvements qui a diverses époques ont changé le relief de cette contrée, Acad. des Sciences, Comptes Rendus, Vol. 14, 1842, pp. 1044-1046; ref. on p. 1045.

[10] O. Maull, Vom Itatiaya zum Paraguay, loc. cit., pp. 314-315; see also scattered descriptions in other parts of the book, esp. p. 52, and pp. 158-171; see also the photographs of these high altitude landforms.

A number of summits are conspicuously beveled at 1,700 to 1,800 meters. Considerable areas of this surface are preserved in these coastal mountains. Lesser summits, and shoulders on the sides of the higher ones describe a second level between 1,400 and 1,500 meters above the sea. Then broad valley bottoms, into which the present streams have been incised, lie between 800 and 1,000 meters above the sea. The crystalline mountains north of the São Paulo Basin and along the border between the states of São Paulo and Minas Geraes (Fig. 1), are composed of considerable stretches of this lower level, about 1,000 meters, with the present streams cut below it in youthful valleys, and with groups of monadnocks (unakas) rising with gentle slopes to 1,400 meters. Similar and still lower erosion levels were reported by Maull in the mountains of Espirito Santo. We shall return to a discussion of these surfaces later.

The Parahyba Graben and the São Paulo Basin.—Fault lines are especially prominent in shaping the surface features of the mountains of southeastern São Paulo state. The escarpment which faces the sea is best developed in this section—standing up 800 meters with very steep slopes only slightly cut by the coastal streams in spite of a heavy rainfall (Figs. 2 and 4). Apparently

FIG. 4a.—Airplane View of the Edge of the Serra do Mar near Santos. In the foreground is a part of the new reservoir, and, to the left, the head of a youthful notch in the escarpment. In the background is the narrow, swampy coastal lowland on which Santos is located.

—Courtesy of São Paulo Tramway, Light & Power Co.

FIG. 4b.—Airplane View of the São Paulo Basin and the Crest of the Serra do Mar, looking toward São Paulo City. The concrete automobile road from São Paulo to Santos can be seen winding down the face of the escarpment.

—Courtesy of São Paulo Tramway, Light & Power Co.

it is a youthful consequent fault scarp of quite recent geologic origin. In back of this there are a number of structural valleys or grabens, the deepest and largest of which is occupied by the middle course of the Rio Parahyba. Two other similar valleys, separated by ranges, lie parallel to this one and between it and the coast. They are occupied by the headwaters of the Parahyba: the Rios Parahybuna and Parahytinga.

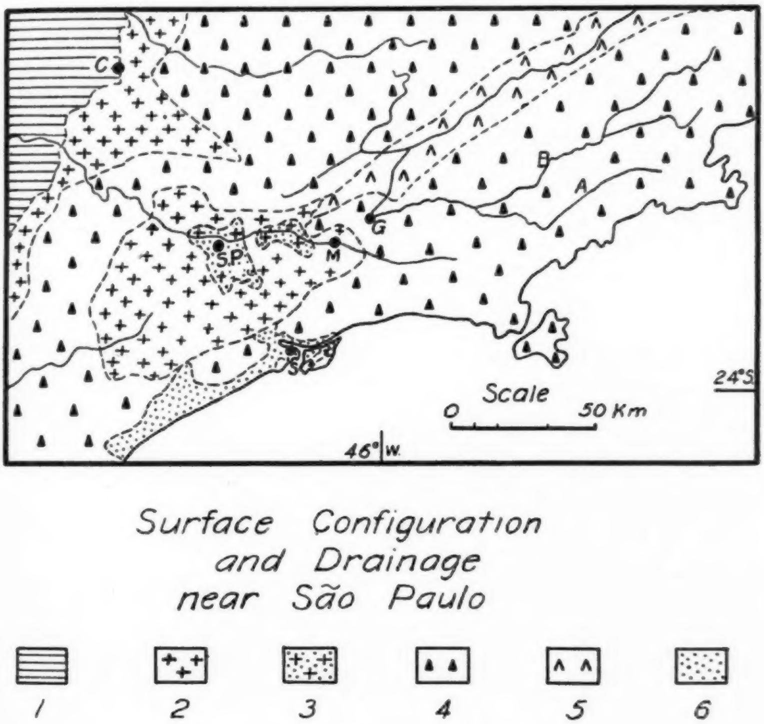

FIG. 5.—Surface Configuration and Drainage near São Paulo.

1 Permo-Triassic Inner Lowland of São Paulo
2 Crystalline Oldland and the São Paulo Basin (800m.)
3 Lacustrine Beds in the São Paulo Basin
4 Crystalline Mountains
5 The Parahyba Valley
6 Coastal Lowlands

C—Campinas; SP—São Paulo; S—Santos; M—Mogy das Cruzes; G—Guararema; A—Rio Parahybuna; B—Rio Parahytinga

An interesting case of river piracy is revealed by the relationships between the Parahyba drainage and that of the Rio Tieté (Fig. 5).[11] The headwaters of the Parahyba rise in the far eastern part of São Paulo state and flow southwestwards. A little east of Mogy das Cruzes, the river turns abruptly in the opposite direction to enter the graben of the middle Parahyba, finally reaching the sea north of Cabo Frio. The Tieté continues in the direction suggested by the Parahyba headwaters. Due to the much more active cutting of the Parahyba, however, there is no wind gap to mark the former connection of the Parahybuna and Parahytinga with the Tieté. The latter stream near Mogy das Cruzes is at an elevation of 740 meters; the Parahyba at Guararema, near the elbow of capture, is about 570 meters, a difference of 170 meters in 24 kilometers. The short left bank tributaries of the Parahyba are cutting youthful ravines headward into the graded surfaces of the Tieté drainage area, threatening still further capture.

Downstream from the elbow of capture, the present Parahyba Valley is by no means a single structural unit. It is rather a series of basins separated by rock sills.[12] Unconsolidated lacustrine deposits[13] form terraces on either side of the valley, but the immediate flood plain of the Parahyba varies from wide, marsh-lined flats, to youthful gorges with channel interrupted by rapids, as it passes from one basin through the intervening rock sill to the next one (Fig. 1). This alternation of basin and rock sill continues downstream as far as Entre Rios (just north of the city of Rio de Janeiro). From this point to the head of the delta, the valley of the Parahyba is narrow and youthful, the channel marked at many places by rapids (Fig. 6).

Southwest of the Parahyba Graben, the same structure is apparently continued, but at a higher level, in the São Paulo Basin (Figs. 1 and 5). In this basin, rimmed by the higher ranges of crystalline mountains, the 800 meter surface is beautifully devel-

[11]The capture of the Tieté is treated by several writers.
See especially:
Gonzaga de Campos, Relatorio sobre o Rio Tieté, São Paulo, 1905;
J. B. Woodworth, Geologic Expedition to Brazil and Chile, Bull. Mus. of Comparative Zoology at Harvard College, Vol. 56, 1912, pp. 1-137, ref. on pp. 106-107; and
O. Maull, Vom Itatiaya zum Paraguay, loc. cit., p. 313.

[12]O. Maull, Vom Itatiaya zum Paraguay, loc. cit., p. 314.

[13]See the bibliography on this subject in J. C. Branner, Outlines of the Geology of Brazil . . . loc. cit., pp. 320-321.

oped. The interfluves preserve this level with fidelity from the very edge of the coastal escarpment inland. This same surface is preserved in the form of shoulders above the intrenched meanders of the Tieté where that stream breaks through the rim of mountains to the northwest. Important evidence as to the origin of this surface is to be had from the contrast in material on which it is developed. Not only is it preserved on the crystalline rocks, but also on the unconsolidated lacustrine beds in the central part of the basin (distinguished as 7a on Figure 1). The Rio Tieté and its tributaries have dissected the floor of the basin to a relief of some 60 or 70 meters, forming broad, swamp-lined valleys subject to inundation in time of heavy rains.

The physiographic interpretation of these various facts is not entirely clear. It seems possible, if not probable, that the Tieté was superimposed on the underlying crystalline structures from a former covering of a sedimentary strata—an extension of the beds still found only a short distance farther west. It seems quite clear, moreover, that the cycle of erosion which resulted

Fig. 6.—Airplane View of Entre Rios and the Rio Parahyba. This important rail junction is located on a small fan at the outlet of a tributary to the Parahyba, which from this point to the head of its delta, flows through a youthful valley interrupted by many rapids. The relation of the street pattern to the landform is interesting.

—Photo by S. H. Holland

in the formation of the baselevel plain and the graded valley through the mountain border, was interrupted by faulting, and by an uplift of some 800 meters. Whether the fault structures of the Parahyba Valley are contemporaneous with the coastal fault scarp, or are much earlier, having been exhumed by differential erosion, cannot be determined on the evidence at hand. Nor can it be definitely established whether the capture of the Tieté headwaters was completed before or during the early stages of the uplift of the 800 meter plain. The maps of the northeastern part of São Paulo state are not sufficiently detailed to give evidence for or against the preservation in that critical area of remnants of the 800 meter level.

The Serra do Espinhaço.—The Serra do Espinhaço, or "Backbone" range, is also included among the crystalline mountains, although it is quite different in character from those which form the margins of the plateau. This name is applied to a commanding and unbroken chain of mountains which extends from central Minas Geraes northward into the state of Bahia (Fig. 1). It separates the drainage of the Rio São Francisco from that of numerous shorter coastal streams such as the Rio Doce. As interpreted by Harder and Chamberlin[14] and others[15], the Serra do Espinhaço is the product of differential erosion, or circumdenudation. The quartzites and schists of which it is composed are much more resistant to the processes of weathering in these latitudes than the granites and gneisses, especially those which are rich in the ferro-magnesian minerals.

Nevertheless, in spite of the distance which separates this range from the coastal mountains, and in spite of the difference in the material which makes them up, there is a striking similarity in the development of erosion levels. The highest surface in the Serra do Espinhaço lies between 1,700 and 1,800 meters. A summit level of uniform and subdued character is here preserved over considerable areas, little touched by later stream dissection. Resting on this surface, too, is a capping of gravels composed

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[14]E. C. Harder and R. T. Chamberlin, The Geology of Central Minas Geraes, Brazil, Journ. of Geol., Vol. 23, 1915, pp. 341-378, and 385-484; ref. especially to first part.

[15]O. A. Derby, The Serra do Espinhaço, Brazil, Journ. of Geol., Vol. 14, 1906, pp. 374-401;

R. Maack, Eine Forschungsreise über das Hochland von Minas Geraes zum Paranahyba, Zeit. der Gesell. für Erdk. zu Berlin, 1926, pp. 310-323; and

B. v. Freyberg, Vorläufige, Ergebnisse einer Forschungsreise durch Minas Geraes (Brasilien), Zeit. der Gesell. für Erdk. zu Berlin, 1929, pp. 12-16.

of very resistant pebbles—in the north containing the diamonds for which this part of Brazil is famous. Then, the summits of a number of the lower ranges of the Serra do Espinhaço preserve the 1,400-1,500 meter surface, as, for example, in the Serra do Curral, south of Bello Horizonte, or the Serra de Ouro Preto, near the city of that name. Then, again, broad valleys descend from this level to valley shoulders between 1,000 and 1,100 meters. Below these, narrow youthful canyons have in places been incised, as the Ribeirão do Funil, near Ouro Preto (Fig. 7 and 7a).

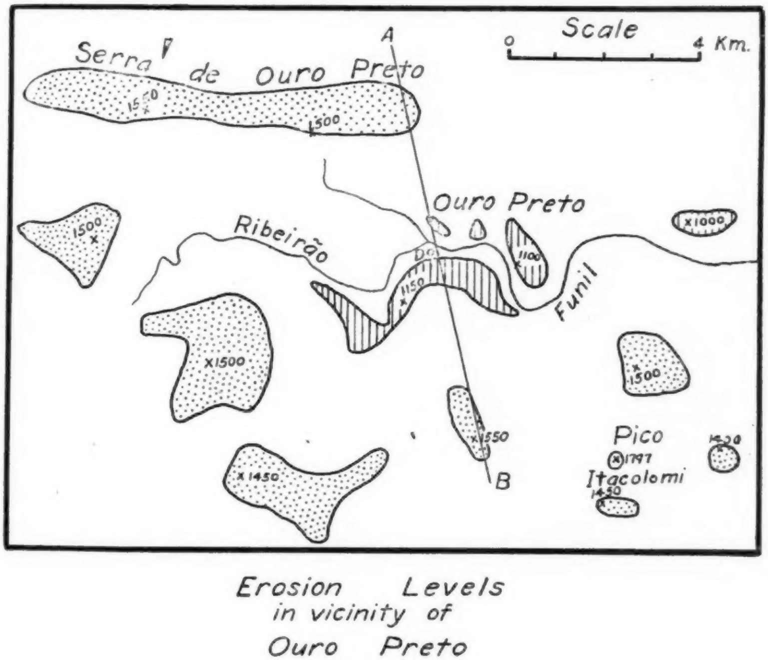


FIG. 7.—Erosion Levels in the Vicinity of Ouro Preto

1 Bench levels, remnants of floor of mature valley, now about 1,100 to 1,150 meters altitude.

2 Remnants of the 1,400-1,500 meter level, forming crest of Serra de Ouro Preto, and shoulders on side of Pico Itacolomi.

3 Actual elevations of selected points.

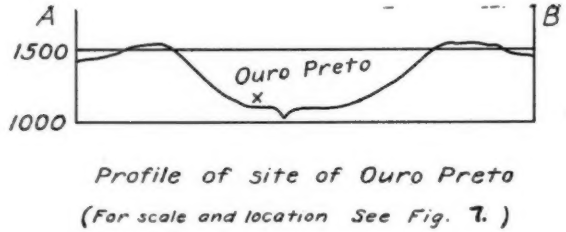


FIG. 7a.—Profile of the Site of Ouro Preto.

With the additional evidence, then, of the Serra do Espinhaço, we can suggest an interpretation of some of these higher levels. The story begins with the slice faulting of the quartzites and schists into the crystalline basement complex at an early period of geologic history.[16] The highest surface (1,700--1,800) is so well developed on the resistant quartzite as to suggest that the whole territory had been reduced to the peneplain stage, with only a few monadnocks remaining. Successive uplifts resulted in the development of lower erosion levels, quickly on the very much weaker granites and gneisses, more slowly on the quartzites and schists. Thus while an extensive baselevel plain was being developed on what is now the 1,000 meter level of the crystalline plateaus, this same period developed on the quartzites of the Serra do Espinhaço only broad, open, mature valleys. The very steep slopes with which the Serra do Espinhaço faces the surrounding plateaus, as the front of the Serra do Curral at Bello Horizonte, represent fault line scarps, probably obsequent[17]; and the steepness of the slopes along the exhumed fault lines provide a measure of the great difference in resistance between the rocks of different types.

THE CRYSTALLINE PLATEAUS

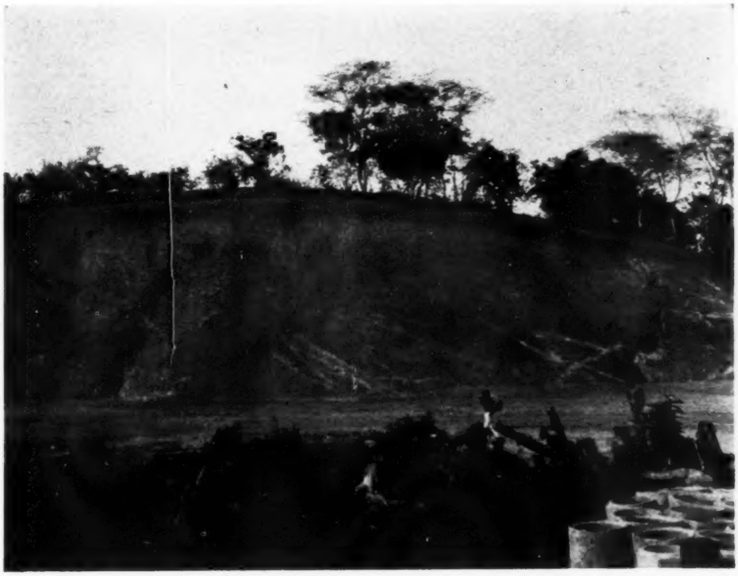
Behind the rim of coastal mountains lie the crystalline plateaus. Three distinct plateaus have been mapped (Fig. 1). The highest one lies between 1,000 and 1,100 meters above the sea, with a few graded, soil-covered swells rising to 1,200 meters, especiallv near its eastern margin. An intermediate plateau at about 800 meters is widespread in eastern Minas Geraes, and also, as we have seen, in parts of São Paulo state. A considerable area of lower level, about 500 meters, is developed in the Pomba Depression of southeastern Minas Geraes and in the middle part of

[16]E. C. Harder, and R. T. Chamberlin, op. cit., p. 352.

[17]W. M. Davis, Nomenclature of Surface Forms on Faulted Structures, Bull. Geol. Soc. Amer., Vol. 24, 1913, pp. 187-216.

the Rio Doce Valley. Near the margins of the lower Parahyba and Pomba are terraces at about 350 meters which are included in this general division of the plateaus.

The surface of the highest of these plateaus is quite different in character from that of the two lower ones. On the highest one the valleys are broad, shallow, and swampy, with aggraded streams. The interfluves are rounded and convex. In spite of its elevated position, this plateau is decreasing in local relief. Von Freyberg interpretes this condition as the result of the deep accumulation of weathered material on the easily decomposed granites and gneisses[18] (Figs. 8 and 9). The character of the drain-



—Photo by the author

FIG. 8.—Road Cut showing Deeply Weathered Gneiss. Although the quartz veins are still in place, the material is unconsolidated to the bottom of the cut and below.

[18] B. v. Freyberg, Ergebnisse geologischer Forschungen in Minas Geraes (Brasilien), loc. cit., p. 278ff, and pp. 284-285.

See also the discussion of channel profiles in relation to the material in which the stream is flowing, in: J. B. Leighly, Toward a Theory of the Morphologic Significance of Turbulence in the Flow of Streams, Univ. Calif. Publ. in Geog., Vol. 6, 1932, pp. 1-22; ref. on pp. 20-21.

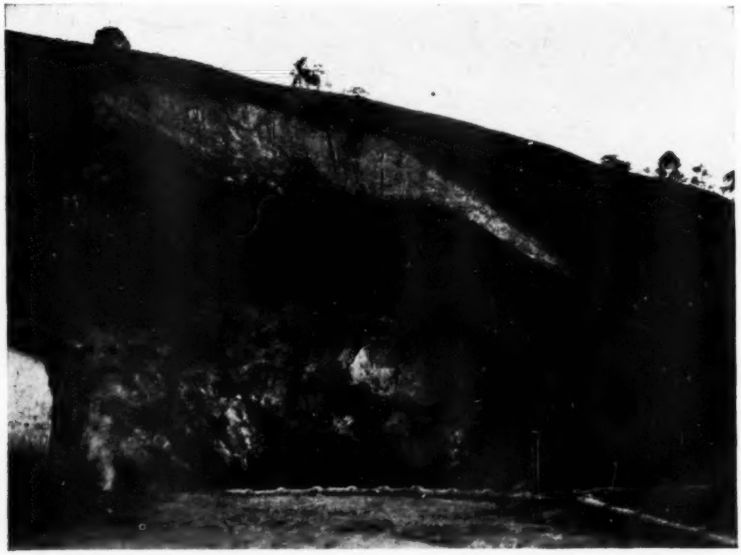


FIG. 9.—View on the Intermediate Plateau showing a Characteristic Landform Detail. Landslides and earthflows are common features on steep slopes in the deeply decomposed soil material.

—Photo by the author

age, however, should not be overlooked. This plateau forms the headwater area of the Rio Grande, a tributary of the Paraná. The Rio Grande, and also the middle part of the master stream, are flowing across resistant beds of diabase. Upstream from the diabase (see Figure 1) the Rio Grande has reached a local baselevel and is aggraded with reference to this baselevel.[19]

The two lower plateaus, on the other hand, exhibit a greater relief. The interfluves are tabular, and the valleys deep and youthful. The local relief is increasing since the streams which drain these areas are obedient to the regional baselevel. In these areas, however, as in the case of the higher plateau, there seems to be a rather striking uniformity of interfluve level[20] (Fig. 10).

[19] P. E. James, The Higher Crystalline Plateau of Southeastern Brazil, Proc. Natl. Acad. of Sci., Vol. 19, 1933, pp. 126-130.

[20] B. v. Freyberg, Ergebnisse geologischer Forschungen in Minas Geraes (Brasilien), loc. cit., does not agree with this. He writes: "Die Bezeichnung 'Rumpf von vorwiegenden Flächencharakter' (quoting Maull) eilt jedoch unserem Wissen voraus, und wenn sie richtig ist, dann ist sie erraten und nicht erweisen." P. 305.

Erosion Levels on the Crystalline Plateaus.—That this uniformity of level is the result of a previous baseleveling seems adequately proved. The widespread occurrence of the 1,000 to 1,100 meter surface and also of the 800 meter surface on a wide variety of rock types, and in different structural units would seem to indicate a previously peneplaned surface below which the present erosion or denudation forms are developing. These same levels have been reported from various parts of the territory under discussion: by Maull from Espirito Santo[21], and by Maack from the state of Paraná southwest of our area[22]. They are found not only on the granites and gneisses, which themselves include a considerable variety of composition[23], but also on the quartzites and schists where they are represented by broad, mature valleys (as on Figure 7). The same levels occur also, as we shall see

—Courtesy of Dr. Peter Rolfs

FIG. 10.—Panorama of the Escola Superior de Agricultura e Veterinaria do Estado de Minas Geraes, near Viçosa. The town of Viçosa lies in the distance on the right hand view. The striking uniformity of the interfluve level is apparent. The photo is taken looking west and northwest from the intermediate plateau a few kilometers north of the scarp of the Pomba Depression.

[21]O. Maull, Vom Itatiaya zum Paraguay, loc. cit., pp. 97, 308, and 312.

[22]R. Maack, Urwald und Savanne im Landschaftsbild des Staates Paraná, Zeit. der Gesel. für Erdk. zu Berlin, 1931, pp. 95-116; ref. on pp. 98-99.

[23]B. v. Freyberg, Ergebnisse geologischer Forschungen . . . loc. cit., geologic map of Minas Geraes;

A. A. Bastos e A. I. Erichsen, Geologia da Folha Barbacena, Serv. Geol. e Mineral. do Brasil, Bol. 25, Rio de Janeiro, 1927;

E. C. Harder and R. T. Chamberlin, op. cit., p. 373;

J. C. Branner, Decomposition of Rocks in Brazil, Bull. Geol. Soc. Amer., Vol. 7, 1896, pp. 255-314; and

O. A. Derby, Decomposition of Rocks in Brazil, Journ. of Geol., Vol. 4, 1896, pp. 529-540.

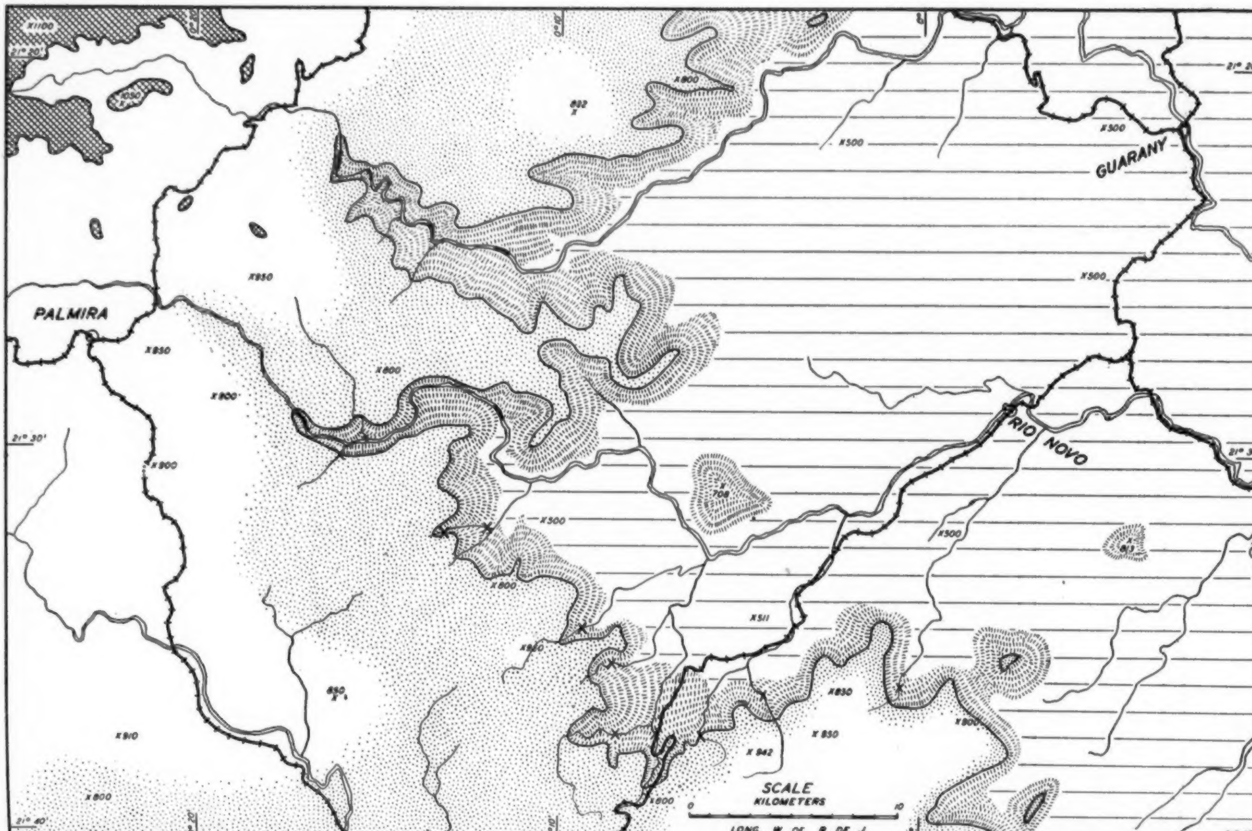

GUARANY
RIO NOVO
PALMIRA
SCALE
KILOMETERS
0
10
LONG. W. OF R. DE J.
21° 20'
21° 30'
21° 40'
X500
X511
X800
X850
X900
X910
X942
X950
X1100
708
813

FIG. 11.—Relations between the Three Crystalline Plateaus near Palmira

1 Lower Crystalline Plateau of the Pomba Depression (about 500m.)
2 Escarpment on inner border of the Lower Plateau
3 Intermediate Crystalline Plateau (about 800m.)
4 Zone of transition between Intermediate and Higher Plateaus, gradually higher elevations toward the northwest
5 Higher Crystalline Plateau (1,000 to 1,100m.)
6 Falls and rapids
7 Actual elevations at selected hill tops

later, on the sedimentary strata and diabase flows of western São Paulo state. These facts suggest base-leveling, varying, to be sure, in stage of development on the different rock types.

The problem remains, then, of the interpretation of these three plateau levels. Do they represent three separate cycles of erosion? Or are they the broken or warped parts of what was originally one peneplain? This problem cannot be conclusively solved with the information now at hand. We may, however, present the evidence for and against a few hypotheses regarding the origin of the levels.

Considerable data bearing on this problem may be gained from a study of the character of the boundaries between the three plateaus. These boundaries are quite different. The line between the higher (1,000-1,100) and the intermediate (800) plateaus is in most places not sharply defined. Along the edge of the crystalline oldland in São Paulo state, the intermediate level rises gradually toward the north until it joins the higher level. The division between these two plateaus in central Minas Geraes, south of the Serre do Espinhaço, is also not abrupt. In the neighborhood of Palmira the transition from the area in which the hill-tops all reach 800 meters (stippled on Figure 11), to that in which the hills reach 1,000 or 1,100 meters (cross-lined on Figure 11), is confined to a zone about 10 kilometers wide. This east-

ern margin of the higher plateau rises in places a little above 1,100 meters, so that it forms a low swell, suggestive of a flexure. It would seem from these relationships that the two levels may well have been one baselevel plain, either upwarped toward the northwest, or downwarped toward the southeast. It seems not improbable that there are some interesting cases of piracy to be worked out along the divide between Paraná drainage on the higher plateau and that of the shorter and more direct coastal streams to the southeast on the intermediate and lower levels.

The division between the two lower plateaus is quite different. A part of this division appears on the map of the vicinity of Palmira (Fig. 11). The drop from 800 to 500 meters is abrupt; in many places bare rock cliffs are actually exposed, and the smaller streams descend over the escarpment in falls while the larger ones are interrupted by stretches of rapids, and have cut narrow, rock-walled, youthful canyons, such as are found along the upper Rio Pomba, or along the Rio Piracicaba, a tributary to the Rio Doce, above Antonio Dias (Fig. 3). The 500 meter level is well developed at the base of the escarpment on Figure 5.

Three possible interpretations suggest themselves: that this escarpment is the result of the erosion of the higher peneplain level to a lower baselevel, which in its own turn has now been uplifted; or that the escarpment is a fault line scarp, exhumed by differential erosion on rocks of varying resistance; or that it is a consequent fault scarp. perhaps somewhat worn back from its original position. The first of these alternatives suggests a relationship not unlike that existing along the front of the Blue Ridge toward the Piedmont in the United States. It requires a rather peculiar form of weathering on the part of the granites and gneisses, a weathering process in which the cliff front produces a very fine and easily removed material so that the cliff may retreat rapidly, even between the stream valleys, and not leave at its base any considerable accumulation of regolith. The arrangement of the escarpment with relation to the Pomba and Rio Doce valleys strongly suggests this interpretation, although the sharpness of the slope, the very slight notching of it by the streams (the section on Figure 11 is more irregular than the average), and the widespread development of the 500 meter level at its very base enforce a consideration of the alternatives.

The hypothesis that this escarpment represents a fault line scarp, exhumed by differential erosion, seems the least tenable of the

three alternatives. Even on the slopes of the Serra do Espinhaço, already interpreted upon geologic evidence as having resulted from the great difference in resistance between the quartzites and schists on the one hand and the granites and gneisses on the other, there are few bare rock cliffs, and even the smaller streams, such as the Ribeirão do Funil (Fig. 7), descend from the mountains in deeply cut canyons heading far back into the range. An even greater difference in rock resistance would have to exist on the two sides of this escarpment between the intermediate and lower plateaus if we are to interpret it is a fault line scarp. Yet von Freyberg's geologic map of Minas Geraes shows no important interruption of the granites and gneisses in this area.

There are many bits of evidence to support the hypothesis that this escarpment is a consequent fault scarp, perhaps somewhat worn back from its original position. Geologic evidence of the fault would, of course, provide the only conclusive proof; and geologic evidence in a country deeply mantled with regolith is extremely difficult to obtain. The behavior of the streams in pouring over this escarpment in falls and rapids seems to suggest that it has only recently been subjected to erosion by them.

The character of the outliers which surmount the three plateaus should give testimony for or against these several hypotheses. By an interesting coincidence, however, they do not, as we shall see. Some of the outliers are made up of massive hilly or even mountainous groups which loom bulkily above the plateau; but most of them are relatively small, isolated conical peaks. A composite profile through southern Minas Geraes, covering a zone running east and west about the latitude of Juiz de Fora (Fig. 3), is presented in Figure 12. The outliers on this profile, and the similar ones which lie farther north, are listed in the following table, in order from west to east, and grouped according to the plateau above which they stand. The elevations are taken from the Minas Geraes state topographic maps. On the higher plateau, most of the outliers come close either to the 1,700-1,800 meter level or to the 1,400-1,500 meter level. On the intermediate plateau, most of the outliers reach 1,000 to a little over 1,100 meters—the elevation of the higher plateau. The Rio Doce valley is not well enough known to be certain that there are any outliers in it; but those which are scattered in apparent confusion over the surface of the Pomba Depression mostly reach altitudes either of 800 meters or 1,000 to 1,100 meters, or in one case of 1,400 meters (note the two outliers on Figure 11).

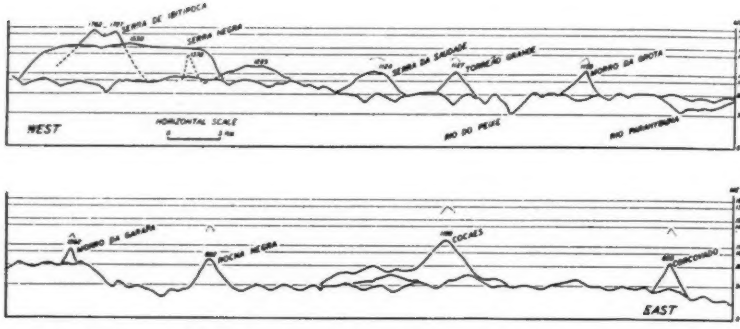


Fig. 12.—Composite Profile through Southern Minas Geraes (for position, see Fig. 2).

These various facts are not as simple as might appear at first sight. If the higher and intermediate plateaus were once one peneplain, then the outliers on the 800 meter level should be raised 200 or 300 meters to return them to their original relationship to the higher levels preserved in the crystalline mountains. Let us, for the moment, suppose that the lower plateau was also once a part of this same peneplain, now separated from it by faulting. Let us return its outliers to their relative position by adding 500 meters to their elevation—to reconstruct all three crystalline plateaus at 1,000 meters. The result is indicated by the dotted summits on Figure 12, and by the figures in parentheses in the table. It shows a striking correspondence with the erosion levels already described in the crystalline mountains. The closest correspondence is found in the case of the largest outliers, such as the Serra Negra on the profile; while the greatest departure from the levels is found in the case of the much eroded conical shaped remnants, such as the Morro da Garapa.

A more definite solution of this problem cannot be warranted by the evidence at hand. From the character of the boundary and the outliers, everything seems to point to the original unity of the higher and intermediate plateaus. Regarding the lower level, however, the evidence tells a more confused story. It seems possible to rule out the hypothesis that the bordering cliff is a fault line scarp, dependent on difference of rock resistance. But whether it represents the removal of weathered granite to a new baselevel plain, or the somewhat eroded front of a consequent fault scarp must remain for the present unanswered.

TABLE I

Elevations of the Chief Outliers on the Crystalline Plateaus of Southeastern Minas Geraes

Outliers on the Higher Level

Serra Negra	1550
Serra de Ibitipoca	1762
Serra de Ibitipoca	1727
Unnamed peak	1378
Unnamed peak	1225

Outliers on the Intermediate Level

(Shown on profile)			(North of profile)		
Serra de Saudade	1124	(1324)	Pedra Bonita	1179	(1379)
Torreão Grande	1127	(1327)	Serra do Japão	1220	(1420)
Morro da Grota	1159	(1359)	Morro das Araras	1225	(1425)
Morro da Garapa	1062	(1262)	Morro do Gamba	1018	(1218)
			Morro da Palestrina	1020	(1220)

Outliers in the Pomba Depression

(Shown on profile)			(North of profile)		
Rocha Negra	892	(1392)	Morro da Boa Esperança	708	(1203)
Cocaes	1199	(1699)	Morro da Floresta	942	(1442)
Corcovado	855	(1355)	Morro do Pensamento	1104	(1604)
			Serra da Neblina	1078	(1578)
			Serra do Descoberto	1455	(1955)
			Pico do Descoberto	803	(1303)
			Serra da Boa Vista	832	(1332)
			Pedra Negra	787	(1287)
			Serra dos Purys	887	(1387)
			Morro da Agua Santa	1154	(1654)
			Morro de Cabeça Preta	1074	(1574)
			Pontão de S. Antonio	844	(1344)
			Pontão do Gloria	1033	(1533)
			Pontão do Brito	768	(1268)
			Serra da Pedra Bonito	760	(1260)

THE AREAS OF STRATIFIED ROCKS

Within the portion of southeastern Brazil under discussion there are two chief areas of stratified rocks. The first of these is the São Francisco basin, occupied mostly by nearly horizontal limestones of early Paleozoic age. This region lies for the most part beyond the range of this study, and for further information on it

the reader is referred to the literature.[24]

The second area of stratified rocks covers the whole western part of Figure 1. This region is involved structurally with a geosyncline, the axis of which is followed quite closely by the Paraná River.[25] The rock strata included in this geosyncline range from Devonian and Permian at the base, resting unconformably on the crystallines of eastern and southern São Paulo, to Cretaceous.[26] Included are also large outpourings of diabase of upper Triassic age.

Immediately west of the crystalline oldland of eastern São Paulo (Fig. 1), the Permian and Triassic formations are relatively weak and have been excavated by the several tributaries of the Alto Paraná to form a characteristic inner lowland (Fig. 13). The rivers cross this inner lowland with sluggish currents, through broad, marsh-lined valleys. The interfluves are graded with convex, gently rounded summits, reaching a general elevation of about 600 to 700 meters above sea level. One formation in the Permian,

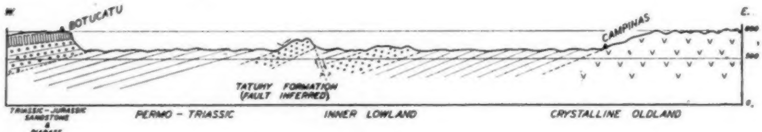


FIG. 13.—Cross Section of the Permo-Triassic Inner Lowland of São Paulo from Campinas to Botucatu (for position see Fig. 2). Geology in part from the Geologic Map of São Paulo (see footnote 5) and from L. Flores de Moraes Rego, A Geologia do Petroleo no Estado de S. Paulo, Bol. 46, Serv. Geol. e Mineral. do Brasil, Rio de Janeiro, 1930.

[24]See especially:

R. R. Walls, The Evolution of the High Plateau of Brazil, Scott. Geog. Mag., Vol. 39, 1925, pp. 229-237;

A. Mettler, Contribution à la Géographie Physique du Bresil: Le Bassin Moyen du Rio São Francisco, Ann. de Geog., Vol. 34, 1925, pp. 510-520;

P. Denis, La Structure Géologique du Bassin du São Francisco Superieur (Après O. Maull et A. Da Silveira), Rev. de l'Amérique Latine, Vol. 12, 1926, pp. 70-75; and

O. Maull, Vom Itatiaya zum Paraguay, loc. cit., pp. 212-228.

See also:

A. D. Gonsalves, Bibliographia da Geologia, Mineralogia e Paleontologia do Brasil, loc. cit.

[25]O. Maull, Vom Itatiaya zum Paraguay, loc. cit., p. 322.

[26]E. Paulo de Oliveira, Geologia Historica do Brasil: Columna Geologica organizada de accordo com os estudos feitas até 31 de Dezembro de 1928, Serv. Geol. e Mineral do Brazil, Rio de Janeiro, 1929.

the Tatuhy formation (Fig. 1), is somewhat more resistant and stands out as a maturely eroded cuesta, scarcely distinguishable near the main streams.

The Permo-Triassic inner lowland is terminated abruptly on the west by the cliffed scarp of the Botucatu cuesta. This feature is held up some 200 meters above the inner lowland by the outcrop of the diabase flows and sills of upper Triassic age—a formation which is widespread throughout the South American continent east of the Andes.[27] The top of this cuesta stands at 800 meters in the south, opposite the similar level on the crystalline oldland (Fig. 13); farther north, where the higher erosion level of 1,000 meters is preserved on the crystallines, the diabase also stands at about 1,000 meters. The main consequent streams, such as the Tieté, pass through the cuesta in steep-sided youthful water gaps, but along its cliffed front the obsequent streams have only succeeded in cutting a few youthful notches. In the north, the distribution of the diabase is complicated, probably by faulting, and numerous isolated islands of asymmetrical shape lie surrounded by the weaker formations of the inner lowland.

One of the largest outpourings of diabase in the world lies just south of this area, in Paraná and Santa Catharina.[28] Just the edge of this appears in the southwest corner of Figure 1. In São Paulo and Minas Geraes west of the diabase cuesta, these flows and sills are covered by sandstones of Jurassic and Cretaceous age. Only where the most vigorous streams have cut through this overlying material is the diabase exposed along the valley bottoms. The Cretaceous sandstones, however, have been removed from the center of the geosyncline by the Paraná and its tributaries and they now only remain along the sides, in São Paulo state some 50 kilometers from the Paraná. Between the tributaries of the main river, these flat-topped interfluves extend fingerlike toward the west, ending abruptly with cliffed sides (Fig. 1). The rivers west of the Botucatu cuesta are youthful, even the Paraná having developed no flood plain above the Guayra Falls.[29]

THE COASTAL ZONE

Of the major surface divisions of southeastern Brazil, the coastal

[29]M. Arrojado, Ribeiro Lisboa, Oeste de São Paulo—Sul de Mato-Grosso, Rio de Janeiro, 1909.

[27]P. Denis, Amérique du Sud, loc. cit., map of structural features of the continent, on p. 9.

[28]C. L. Baker, The Lava Field of the Paraná Basin, Journ. of Geol., Vol. 31, 1923, pp. 66-79.

zone remains to be described. Here we find that emergence has continued to recent time. As a whole, the coast is difficult to approach from the sea. The harbors of Rio de Janeiro, Santos, and Victoria, and a few lesser places where protected anchorages may be made, serve only to emphasize the general lack of harbors. The coastal zone varies in width from some 75 kilometers on the Parahyba Delta, to nothing at all southwest of Rio de Janeiro where the steep slopes of the plateau escarpment plunge directly beneath the sea (Fig. 1).

Many of the landforms and shore forms characteristic of this zone are illustrated in the vicinity of Rio de Janeiro (Fig. 14).

FIG. 14.—Airplane View of the Pão d'Assucar at the Mouth of Guanabara Bay. Parts of the city of Rio de Janeiro can be seen between the "sugar-loaf" mountains. The curving beach in the left middle distance is the famous Praia Copacabana, facing the open Atlantic.

—Photo by Aircraft Operating Co.

The spectacular scenery of this place is widely known, but the forms for which it has become justly famous are repeated at many other places from Victoria to Paranagua. An outlying mountain block lies parallel to the coast of Rio de Janeiro, separated from the main fault escarpment by lowlands and dissected terraces. A down-faulted section in the middle of this range has permitted the

entrance of the sea, and the formation inland of a partially drowned lowland, or *baixada*. This is known as the Baixada Fluminense. Like the other baixadas of the coast, the surface is composed of knobby hills, deeply mantled with soil, and with a relief of only some 40 to 50 meters. The valleys are shallow, marshy, and aggraded. The shore of the Baixada Fluminense where it touches Guanabara Bay is fringed with mangrove swamps, and the water off-shore is shallow.

It is only where the ocean waves reach, or have reached in geologically recent time, the outlying mountain range that the sugar-loaf mountain forms, so familiar in the Rio de Janeiro scenery, are produced. Brandt[30] has interpreted these bare rock knobs as having been cleaned of their covering of residual soil material by the washing of waves around their bases. The knobby shape is a normal form of weathering on crystalline rocks under a humid tropical climate, but the unusual exposure of bare rock is the result of wave action, and such hills as the Sugar Loaf (Pão D'Assucar) are found only close to the sea. Similar forms occur at many places along the coast.[31]

That the shore is one of emergence is indicated by many things. Many of the sugar-loaf hills are now separated from the highest waves by sandy flats. Crescentic sand bars are festooned from headland to headland, and behind them shallow lagoons are in the process of extinction by filling and by the encroachment of mangrove. The rocky headlands have wave-cut terraces on their exposed fronts.[32] These various features, all well illustrated in the vicinity of Rio de Janeiro, occur elsewhere along the coast. Other bays, similar to Guanabara, are either now completely filled in, as the Iguape lowland southwest of Santos, or are in process

[30]B. Brandt, Die tallosen Berge an der Bucht von Rio de Janeiro, Mitt. der Geog. Gesel. in Hamburg, Vol. 30, 1917, pp. 1-68; including an important comparison of weathering and erosion processes in middle and low latitudes.

[31]R. A. Hehl, Das Brasilianische Küstenland zwischen 21° und 23° Südlicher Breite, Pet. Mitt., Vol. 28, 1882, pp. 443-447;

B. Brandt, Die Landschaft an der Bucht von Santos, Mitt. der Geog. Gesel. in Hamburg, Vol. 32, 1919, pp. 93-116;

P. Denis, Le Paysage de la Baie de Rio de Janeiro, Rev. de l' Amérique Latine, Vol. 2, 1922, pp. 155-163; and

J. R. Guinazu, Algumas Observaciones sobre geomorphologia, suelo, y clima de Rio de Janeiro, São Paulo, y sus zonas adyacentes (Brasil), Gaea, Vol. 3, 1928, pp. 257-290.

[32]E. Backheuser, A Faixa Litorania do Brasil Meridional, Hoje e Ontem. Rio de Janeiro, 1918.

of being filled in, as the Bahia de Sepitiba. The characteristic association of sugar-loaf mountains, festooned sand bars, bay head lagoons and flats, and partially drowned baixadas, remnants of an earlier period of coastal depression, are developed, perhaps less strikingly at Iguape, Santos,[33] and in the north at Victoria.

Deltas form another type of coastal landscape, quite different from those just described. Flattish surfaces are rare in southeastern Brazil. Even the baixadas are distinctly hilly. But the deltas of the Parahyba and of the Doce are large tracts of comparatively level alluvium which the rivers cross in slightly incised valleys in response to the most recent coastal uplifts (Fig. 15). The shore of both deltas has been prograded with arcuate form.

—Photo by S. H. Holland

Fig. 15.—Airplane View of the Rio Parahyba Delta. The city of Campos is in the distance. In the foreground are sugar fields and a sugar mill or "engenho." Such level land as this is rare in southeastern Brazil.

[33]Estado de São Paulo, Commissão Geographica e Geologica: Exploração do Rio Ribeira de Iguape, 2a. Edição, São Paulo, 1914;

Exploração do Littoral, la. Secção, Cidade de Santos a fronteira do Estado do Rio de Janeiro, São Paulo, 1915;

Exploração do Littoral, 2a. Secção, Cidade de Santos a frontiera do Estado de Parana, São Paulo, 1920;

Exploração do Rio Juqueryquere, 2a. Edição, São Paulo, 1919.

CONCLUSION

From the foregoing we may see that we have in southeastern Brazil a land of the greatest variety and complexity of surface configuration. The present paper presents some of the details of surface form which provide so necessary a basis for geographic studies in this area. It also suggests some of the physiographic problems which were uncovered. Here is a fine new field for the student of geomorphology. The investigation of the physiographic history of the Rio Doce with its well-preserved array of terraces and erosion levels would be a fascinating and critical study. With the aid of the new maps being published by the state governments, especially of São Paulo and Minas Geraes, the more refined technique which has recently been applied to Appalachian studies might well be utilized in unraveling the physiographic history of this area. There is a wealth of material, also, for the investigation of the evolution of minor landforms under the moist frost-free conditions of the tropical margins. It is hoped that specialists in geomorphology may be stimulated to undertake the study of some of these problems.